DISCLAIMER

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Please note that this document, its sectional content, structure, ordering, and requirements are in a draft state and are not yet ready for final posting in their current form. We are also developing and organizing more front matter at this time. However, this document is provided as is at this time as an up-to-date version of the current requirements. ***They are provided solely for the purpose of facilitating on-going discussions and do not yet represent the final version.***

Voluntary Voting System Guidelines VVSG 2.0

Draft Recommendations for Requirements for the Voluntary Voting System Guidelines 2.0

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Prepared for the ***Election Assistance Commission***

At the direction of the
Technical Guidelines Development Committee

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Public Working Groups discussed and developed guidance to inform the development of requirements for the VVSG.

- **The Election Process Working Groups: Pre-Election, Election, and Post-Election Process Working Groups** performed a great deal of up-front work to collect locale-specific election process information and, from that, to create coherent process models.
- **The Interoperability Working Group** handled voting system interoperability including common data format (CDF) modeling and schema development.
- **The Human Factors Working Group** handled human factors-related issues including accessibility and usability.
- **The Cybersecurity Working Group** handled voting system cybersecurity-related issues include various aspect of security control and auditing capabilities.
- **The Testing Working Group** handled voting system testing-related issues including what portions of the new VVSG need to be tested and how to test them.

Executive Summary

The United States Congress passed the Help America Vote Act of 2002 (HAVA) to modernize the administration of federal elections and to establish the U.S. Election Assistance Commission (EAC) to provide guidance to the states in their efforts to comply with the HAVA administrative requirements. Section 202 of HAVA directs the EAC to adopt voluntary voting system guidelines, and to provide for the testing, certification, decertification, and recertification of voting system hardware and software.

The purpose of the guidelines is to provide a set of specifications and requirements against which voting systems can be tested to determine if they provide all the basic functionality, accessibility, and security capabilities required of voting systems. This document, the **Voluntary Voting System Guidelines Version 2.0 Requirements** (referred to herein as the Guidelines or VVSG 2.0), is the fifth iteration of national level voting system standards. The Federal Election Commission published the first two sets of federal standards in 1990 and 2002. The EAC then adopted Version 1.0 of the VVSG on December 13, 2005. In an effort to update and improve version 1.0 of the VVSG, on March 31, 2015, the EAC commissioners unanimously approved VVSG 1.1.

The VVSG 2.0 is a departure from past versions in that a set of principles and associated guidelines were first developed to describe how, at a high-level, voting systems should be designed, developed, and how they should operate. The VVSG 2.0 requirements were then derived from those principles and guidelines. The VVSG 2.0 Requirements fits within a framework of documents under the EAC voting system certification program that include:

- VVSG 2.0 Principles and Guidelines
- VVSG 2.0 Requirements
- VVSG 2.0 Testing and Certification Manual

The Guidelines were designed to meet the challenges ahead, to replace decade's old voting machines, to improve the voter experience, and provide necessary safeguards to protect the integrity of the vote. All sections of the prior VVSG have been reviewed, rethought, and updated to meet modern expectations about how voters should interact with the voting system and how voting systems should be designed and developed. The VVSG 2.0 requirements represent the latest in both industry and technology best practices, requiring significant updates in many aspects of voting systems.

The Guidelines allow for an improved and consistent voter experience, enabling all voters to vote privately and independently, ensuring votes are marked, verified and cast as intended, and that the final count represents the true will of the voters. Federal accessibility standards, Section 508, and Web Content Accessibility Guidelines are referenced and highlighted. Voter interface requirements have been updated to incorporate recent usability research and

interactions that result from modern devices and now fully support accessibility throughout the voting process.

The cybersecurity of voting systems has never been more important. Indeed, attacks from nation state actors on our elections infrastructure in 2016 led to a critical infrastructure designation. To limit the attack surface on voting systems, the Guidelines require that any election system, such as an e-pollbook or election reporting system, be air-gapped from the voting system. To ensure the integrity of the vote, methods to detect errors through the combined use of an evidence trail and regular audits, including risk-limiting audits (RLAs), compliance audits, and ballot-level audits, are now supported. There is a dedicated section on ballot secrecy, preventing voter information from being carried through to the voting system, and two-factor authentication is now mandated for critical voting operations. Cryptographic protection of data and new system integrity requirements ensure that security protections developed by industry over the past decade are built into the voting system. These include risk assessment and supply chain risk management, secure configurations and system hardening, exploit mitigation, sandboxing and runtime integrity.

The VVSG 2.0 requires the voting system to include the capability to use common data formats defined by NIST and public working groups. The common data formats were created to make election data more transparent and interoperable. These formats can be used in addition to any native formats used by the manufacturer. Defensive coding practices, reliability and electrical requirements were reviewed, updated, and streamlined. Finally, guidance relevant to testing and certification has been moved to the EAC's testing and certification manual.

This document was produced by the EAC's Technical Guidelines Development Committee (TGDC) working in conjunction with the National Institute of Standards and Technology (NIST) to aid in developing guidelines for voting equipment and technologies for making accessible, accurate and secure elections possible.

Table of Contents

Introduction

This document, the *Voluntary Voting System Guidelines 2.0 Requirements* (*VVSG 2.0*), is the third version of national level voting system standards. Adherence to the Guidelines is governed by state and territory-specific laws and procedures.

VVSG 2.0 is a recommendation from the Technical Guidelines Development Committee (TGDC) to the Election Assistance Commission (EAC) for a voting system standard written to address the next generation of voting equipment.

This version offers a new approach to the organization of the guidelines. It is a complete re-write of the VVSG 1.1 and contains new and expanded material in many areas, including reliability, usability, accessibility, and security.

The requirements are more precise, more detailed, and written to be clearer to voting system manufacturers and test laboratories. The language throughout is written to be readable and usable by other audiences as well, including election officials, legislators, voting system procurement officials, various voting interest organizations and researchers, and the public at large.

The VVSG 2.0 requirements were derived from the VVSG 2.0 Principles and Guidelines, which contain 15 major principles and 63 associated guidelines that cover voting system design, development, and operations.

How the VVSG is to be Used

This document will be used primarily by voting system manufacturers and voting system test laboratories as a baseline set of requirements for voting systems to which states will add their state-specific requirements as necessary. This audience includes:

- Manufacturers, who will use the requirements when they design and build new voting systems as information about how voting systems should perform or be used in certain types of elections and voting environments.
- Test laboratories who will refer to this document when they develop test plans for the analysis and testing of voting systems as part of the national certification process and state certification testing to verifying whether the voting systems have satisfied the VVSG 2.0 requirements.

This document, therefore, serves as an important, foundational tool that defines a baseline set or requirements necessary for ensuring that the voting systems used in U.S. elections will be secure, reliable, and easy for all voters to use accurately.

Scope

The scope of the VVSG 2.0 is limited to equipment acquired by states and certified by the EAC. The VVSG 2.0 covers pre-voting, voting, and post-voting operations consistent with the definition of a ***voting system*** in the Help America Vote Act (HAVA) Section 301, which defines a voting system as the total combination of mechanical, electromechanical, or electronic equipment (including the software, firmware, and documentation required to program, control, and support the equipment), that is used to define ballots; cast and count votes; report or display election results; and maintain and produce any audit trail information.

The ***voting system*** as defined in the VVSG 2.0 is:

Equipment (including hardware, firmware, and software), materials, and documentation used to enact the following functions of an election:

1. *define elections and ballot styles,*
2. *configure voting equipment,*
3. *identify and validate voting equipment configurations,*
4. *perform logic and accuracy tests,*
5. *activate ballots for voters,*
6. *record votes cast by voters,*
7. *count votes,*
8. *label ballots needing special treatment,*
9. *generate reports,*
10. *export election data including election results,*
11. *archive election data, and*
12. *produce records in support of audits.*

As part of the voting system scope, HAVA Section 301 mandates five additional functional requirements to assist voters. Although these requirements may be implemented in a different manner for different types of voting systems, all voting systems must provide these capabilities, which are reflected in the VVSG 2.0 requirements:

1. Permit the voter to verify (in a private and independent manner) their choice before the ballot is cast and counted.
2. Provide the voter with the opportunity (in a private and independent manner) to change their choice or correct any error before the ballot is cast and counted.
3. Notify the voter if they have selected more than one candidate for a single office, inform the voter of the effect of casting multiple votes for a single office, and provide the voter an opportunity to correct the ballot before it is cast and counted.
4. Be accessible for individuals with disabilities in a manner that provides the same opportunity for access and participation (including privacy and independence) as for other voters.

5. Provide alternative language accessibility pursuant to Section 203 of the Voting Rights Act.

Section 301(a)(3)(B) also states that there should be "… at least one direct recording electronic voting system or other voting system equipped for individuals with disabilities at each polling place". Best practice indicates that to ensure the same opportunities as other voters, sufficient numbers of accessible voting stations (including alternative language ballot features) should be provided in a polling place. This will help to encourage those voters who can benefit from the accessibility features to use them. Procedures and training for poll workers on the operation of the accessible voting stations are also needed to support this usage.

The VVSG 2.0 definition does not expand the HAVA definition but focuses it on election processes. The VVSG 2.0 principles, guidelines, and requirements apply to the election process functions and, by extension, to the voting devices that implement these functions.

The scope of most VVSG 2.0 requirements applies to the entire voting system as opposed to specific devices, thus permitting the manufacturer more freedom to implement the requirements as they choose. However, when the scope of a requirement is limited to a specific function, that information is included in the text of the requirement, for clarity. For example:

- "A voting system's electronic display must be capable of..."
- "Scanners and ballot marking devices must include…"
- "The cryptographic E2E protocol used in the voting system must…"

Implications for Networking and Remote Ballot Marking

Traditionally, ballots have been cast at polling places or through mail-in absentee ballots. There has been a growing trend to provide flexibility for voters to vote early in-person at vote centers or at home using remote ballot marking applications. These innovative methods of voting provide additional paths to voting independently and privately for voters including those with disabilities. Likewise, advances in technology have led to efficiencies in election administration, including increasing use of e-pollbooks for easy check-in and electronic election results reporting for timely aggregation of unofficial election results.

These additional election systems require network access to synchronize voter records, access remote ballot marking applications, and transmit unofficial election results. Securing these systems is outside the scope of VVSG 2.0. However, the benefits and risks associated with the use of these technologies was carefully considered when developing the Guidelines, and requirements were developed to ensure that the voting system is isolated from these additional election systems.

This section clarifies the boundary between the external election systems and the voting system as well as the use of wireless technologies within polling places or vote centers.

External Network Connections

VVSG 2.0 does not permit devices or components using external network connections to be part of the voting system. There are significant security concerns introduced when networked devices are then connected to the voting system. This connectivity provides an access path to the voting system through the Internet and thus an attack can be orchestrated from anywhere in the world (e.g., Nation State Attacks). The external network connection leaves the voting system vulnerable to attacks, regardless of whether the connection is only for a limited period or if it is continuously connected. The types of attacks include the following:

- The loss of confidentiality and integrity of the voting system and election data through malware injection or eavesdropping
- The loss of availability to access data or perform election process (e.g., ransomware attack)

The VVSG 2.0 requirements address the concerns of external network connections (see 14.2-E *External Network Restrictions and 15.4-B Secure Configuration Documentation)*. Externally-networked devices or components such as for e-pollbooks or transmission of election results must be physically isolated from the voting system. This physical isolation can be described as an *airgap* between any systems that have an external network connection.

Remote Ballot Marking

Remote ballot marking is defined as an election system for voters to mark their ballots outside of a voting center or polling place. These systems are a tool to be used to enable no excuse absentee voting. They allow a voter to receive a blank ballot to mark electronically, print, and then cast by returning the printed ballot to the elections office. A voter may electronically fill out their ballot with a state-provided web application. Remote ballot marking applications provide another path to voting independently and privately for voters including those with disabilities.

The VVSG 2.0 requirements apply to devices used to mark ballots inside a polling place or vote center. They do not apply to remote ballot marking devices and applications. The VVSG 2.0 requirements affect only those voting system devices that constitute a voting system and that are submitted for testing and certification. For remote ballot marking, the voter uses a web application, their own personal device, and an external network (i.e., the Internet).

It should be noted that remote ballot marking applications need to comply with accessibility laws such as the Americans with Disabilities Act. VVSG 2.0 requirements that address the accessibility and usability for the electronic interface of a remote ballot marking software application can serve as an informative resource for developers of these systems. For example, 8.2-A — Federal standards for accessibility, identifies the WCAG Level AA checkpoints in the Section 508 Standards as a requirement for voting system electronic interfaces.

Internal Wireless Networks

Internal Wireless Networks wirelessly communicate or transfer information between two or more devices. Examples include use of wireless (Bluetooth) mice and keyboards or (Wi-Fi) printers. There are also growing trends towards using wireless technology for assistive devices such as headsets or hearing aids.

Wireless technology within the voting system introduces security concerns in that wireless networks can provide an entry point to the voting system for attackers. The security configurations for devices used in wireless technologies are not all equally secure, with some configured to provide more strength than others.

The VVSG 2.0 requires that a voting system be incapable of broadcasting a wireless network (see 14.2-D *Wireless Communication Restrictions and 15.4-B.1 Documentation for disabled wireless)*. Instead, a voting system could use *wired* technology, e.g., Ethernet cables, to connect devices such as printers.

Wireless personal assistive technologies are still possible, however. A voter may use their Bluetooth headset by using an adapter connected to the voting system's 3.5mm standard headphone jack, which creates a Bluetooth wireless connection between the adaptor and the headset. This effectively limits the attack surface to that of the headphone jack's analog communications without limiting the use of the voter's personal assistive technology.

Major changes from VVSG 1.1 to VVSG 2.0

There are many new or updated requirements, strengthening the security, interoperability, and usability and accessibility of voting systems.

Principle 1 - High Quality Design

- Functional equipment requirements are organized as phases of running an election:
    - Election and Ballot Definition

    - Pre-election Setup and logic and accuracy (L&A) testing
    - Opening Polls, Casting Ballots
    - Closing Polls, Results Reporting
    - Tabulation, Audit
    - Storage
- Requirements dovetail with cybersecurity in areas including:
    - Pre-election setup
    - Audits of barcodes versus readable content for ballot marking devices (BMDs)
    - Audits of scanned ballot images versus paper ballots
    - Audits of Cast Vote Record (CVR) creation
    - Content of various reports
    - Ability to match a ballot with its corresponding CVR
- Guidance relevant to testing and certification has been moved to the EAC testing and certification manuals.

Principle 2 - High Quality Implementation

- Adds requirement to document and report on user-centered design process by developer to ensures system is designed for a wide range of representative voters, including those with and without disabilities, and election workers (*P 2.2)*

Principle 3 – Transparent

- Addresses transparency from the point of view of documentation that is necessary and sufficient to understand and perform all operations

Principle 4 - Interoperable

- Ensures that devices are capable of importing and exporting data in common data formats
- Requires manufacturers to provide complete specification of how the format is implemented
- Requires that encoded data uses publicly available, no-cost method
- Uses common methods (for example, a USB) for all hardware interfaces
- Permits Commercial-off-the-Shelf (COTS) devices as long as relevant requirements are still satisfied

Principle 5 - Equivalent and Consistent Voter Access

- Applies to all modes of interaction and presentation throughout the voting session, fully supporting accessibility

Principle 6 - Voter Privacy

- Distinguishes voter privacy from ballot secrecy and ensures privacy for marking, verifying, and casting the ballot

Principle 7 - Marked, Verified, and Cast as Intended

- Updates voter interface requirements such as font, text size, audio, interaction control and navigation, scrolling, and ballot selections review
- Describes requirements that are voting system specific, but derived from Federal accessibility law

Principle 8 - Robust, Safe, Usable, and Accessible

- References Federal accessibility standards, Section 508 and Web Content Accessibility Guidelines 2.0 (WCAG 2.0)
- Updates requirements for reporting developer usability testing with voters and election workers

Principle 9 - Auditable

- Focuses on machine support for post-election audits
- Makes software independence mandatory
- Supports paper-based and end-to-end (E2E) verifiable systems
- Supports all types of audits, including risk-limiting audits (RLAs), compliance audits, and ballot-level audits

Principle 10 - Ballot Secrecy

- Includes a dedicated ballot secrecy section
- Prevents association of a voter identity to ballot selections

Principle 11 - Access Control

- Prevents the ability to disable logging
- Bases access control on voting stage (Pre-voting, Activated, Post-voting)
- Does not require role-based access control (RBAC)
- Requires multi-factor authentication for critical operations:
    - Software updates to the certified voting system
    - Aggregating and tabulating
    - Enabling network functions
    - Changing device states, including opening and closing the polls

- Deleting the audit trail
- Modifying authentication mechanisms

Principle 12 - Physical Security

- Requires using only those exposed physical ports that are essential to voting operations
- Ensures that physical ports are able to be logically disabled
- Requires that all new connections and disconnections be logged

Principle 13 - Data Protection

- Clarifies that there are no hardware security requirements (for example, TPM (trusted platform module))
- Requires Federal Information Processing Standard (FIPS) 140-2 validated cryptographic modules (except for end-to-end cryptographic functions)
- Requires cryptographic protection of various election artifacts
- Requires digitally signed tabulation reports
- Ensures transmitted data is encrypted with end to end authentication

Principle 14 - System Integrity

- Requires risk assessment and supply chain risk management strategy
- Removes non-essential services
- Secures configurations and system hardening
- Exploit mitigation (for example, address space layout randomization (ASLR) data execution prevention (DEP) and free of known vulnerabilities
- Requires cryptographic boot validation
- Requires authenticated updates
- Ensure sandboxing and runtime integrity

Principle 15 - Detection and Monitoring

- Ensures moderately updated list of log types
- Requires firewalls and Intrusion Detection System for networked systems
- Detection systems must be updateable
- Requires digital signatures or whitelisting for voting systems
- Requires malware detection focusing on backend PCs

VVSG document structure

This document contains the following sections:

- **Principles and Guidelines:** High level system design goals
- **Requirements:** Detailed technical requirements that support the principles and guidelines
- **Appendix A - Glossary:** Terminology used in requirements and informative language
- **Appendix B - List of all Requirements:** A summary listing of the titles of all requirements
- **Appendix C - References:** References to external sources used in the writing of the requirements

Conformance Information

This section provides information and requirements about how manufacturers can use the features of this document to assess whether a voting system conforms to the VVSG Principles and Guidelines. Conformance here means only that the requirements of the VVSG have been met; it does not imply certification according to the EAC's voting system certification program.

Organization and Structure of VVSG 2.0 Requirements

The VVSG 2.0 requirements are organized and numbered according to the principles and guidelines they are most applicable to. They have the following fields:

- Number and title of each requirement
- Text of each requirement
- Optional informative discussion field
- Optional informative fields for source and applicability of the requirement

As an example, Requirement 8.1-B contains all four fields:

8.1-B – Flashing

If the voting system emits lights in flashes, there must be no more than three flashes in any one-second period.

Discussion

This requirement has been updated to meet WCAG 2.0 and Section 508 software design issue standards

External references:	WCAG 2.0/Section 508
Prior VVSG sources:	VVSG 1.1 - 3.2.5.a.i
Applies to:	Electronic interfaces

Requirements are indicated by the presence of a unique number in the left margin, followed by a descriptive title.

The **Discussion field** may aid in understanding the requirement but does not itself constitute a requirement.

The optional informative fields show the source of the requirement and to which functions or devices of the voting system it applies:

- *External references:* specifications or laws that are sources for the requirement.
- *Prior VVSG sources:* previous VVSG requirements that the current requirement is updating.
- *Applies to:* indicates the type of voting system function or device to which the requirement applies. This field is used only if the applicability of a requirement is not already clear in the requirement text.

Navigating through Requirements

You can navigate through the requirements:

From the list of principles and guidelines. Links in this list go to the requirements that support each principle or guideline.

From the list of all requirements in Appendix B. This list lets you quickly identify requirements in each section. Each title is linked to the requirement text.

In addition, features of the Adobe Acrobat Reader can be useful. More information can be found in Adobe's help site under **Navigating PDF Pages**.

Technical standards and terms used in the requirements

There are a number of technical standards that are incorporated in the Guidelines by reference. These are referred to by title in the body of the document. The full citations for these publications are provided in Appendix C. This appendix also includes other references that may be useful for understanding the information. References in requirements and informative text are linked to Appendix C.

The requirements contain terms describing function, design, documentation, and testing attributes of voting system hardware, software, and telecommunications. Unless otherwise specified, the intended sense of technical terms is that which is commonly used by the information technology industry. In some cases, terminology is specific to elections or voting systems. Requirements that use words with special meanings are linked to their definitions in Appendix A, Glossary.

Conformance Language

The text of a requirement is referred to as *normative*, meaning that the text constitutes the requirement and must be satisfied when implementing and testing the voting device or system. Text in this document that is not part of a requirement is referred to as *informative*, meaning that it is for informational purposes only and does not contain requirements.

The following keywords are used to convey conformance requirements:

Must indicates a mandatory requirement. Synonymous with "is required to."

Must not also indicates a mandatory requirement, but the requirement is to *not* do something.

May indicates an optional, permissible action and often suggests one possible way of conforming to a more general requirement.

What is neither required nor prohibited by the language of the requirements is permitted.

Informative parts of this document include discussion, examples, extended explanations, and other matters that are necessary to understand the VVSG Principles and Guidelines and how to conform to them. Informative text may serve to clarify requirements, but it is not otherwise applicable to achieving conformance. Unless otherwise specified, a list of examples should not be interpreted as excluding other possibilities that were not listed.

Implementation Statement

A voting system conforms to the VVSG Principles and Guidelines if all stated requirements that apply to that voting system and all of its devices are fulfilled. The implementation statement

documents the requirements that have been implemented by the voting system, the optional features and capabilities supported by the voting system, and any extensions (that is, additional functionality) that it implements.

The implementation statement may take the form of a checklist to be completed for each voting system submitted for conformity assessment. It is used by test labs to identify the conformity assessment activities that are applicable.

The implementation statement must include:

- Full product identification of the voting system, including version number or timestamp
- Separate identification of each device that is part of the voting system
- Device capacities and limits
- List of languages supported
- List of accessibility capabilities
- List of voting variations supported
- Devices that support the core functions and how they do it
- List of requirements implemented
- Any extensions also included in the voting system
- Signed document that the information provided accurately characterizes the system submitted for testing

Extensions to the VVSG 2.0

Extensions are additional functions, features, or capabilities included in a voting system that are not defined in the requirements. To accommodate the needs of states that may impose additional requirements and to accommodate changes in technology, extensions are permitted. However, an extension is not allowed to contradict or relax requirements that would otherwise apply to the system and its devices.

The VVSG 2.0 - Principles and Guidelines

The VVSG 2.0 consists of 15 principles and 63 guidelines. Together these principles and guidelines cover voting system design, development, and operations.

Principle 1: HIGH QUALITY DESIGN

The voting system is designed to accurately, completely, and robustly carry out election processes.

1.1 - The voting system is designed using commonly-accepted election process specifications.

1.2 - The voting system is designed to function correctly under real-world operating conditions.

1.3 - Voting system design supports evaluation methods enabling testers to clearly distinguish systems that correctly implement specified properties from those that do not.

Principle 2: HIGH QUALITY IMPLEMENTATION

The voting system is implemented using high quality best practices.

2.1 - The voting system and its software are implemented using trustworthy materials and best practices in software development.

2.2 - The voting system is implemented using best practice user-centered design methods that consider a wide range of representative voters, including those with and without disabilities, and election workers.

2.3 - Voting system logic is clear, meaningful, and well-structured.

2.4 - Voting system structure is modular, scalable, and robust.

2.5 – The voting system supports system processes and data with integrity.

2.6 - The voting system handles errors robustly and gracefully recovers from failure.

2.7 - The voting system performs reliably in anticipated physical environments.

Principle 3: TRANSPARENT

The voting system and voting processes are designed to provide transparency.

3.1 - The documentation describing the voting system design, operation, accessibility features, security measures, and other aspects of the voting system can be read and understood.

3.2 - The processes and transactions, both physical and digital, associated with the voting system are readily available for inspection.

3.3 - The public can understand and verify the operations of the voting system throughout the entirety of the election.

Principle 4: INTEROPERABLE

The voting system is designed to support interoperability in its interfaces to external systems, its interfaces to internal components, its data, and its peripherals.

4.1 - Voting system data that is imported, exported, or otherwise reported, is in an interoperable format.

4.2 - Standard, publicly-available formats for other types of data are used, where available.

4.3 - Widely-used hardware interfaces and communications protocols are used.

4.4 - Commercial-off-the-shelf (COTS) devices can be used if they meet applicable VVSG requirements.

Principle 5: EQUIVALENT AND CONSISTENT VOTER ACCESS

All voters can access and use the voting system regardless of their abilities, without discrimination.

5.1 - Voters have a consistent experience throughout the voting process within any method of voting.

5.2 - Voters receive equivalent information and options in all modes of voting.

Principle 6: VOTER PRIVACY

Voters can mark, verify, and cast their ballot privately and independently.

6.1 - The voting process preserves the privacy of the voter's interaction with the ballot, modes of voting, and vote selections.

6.2 - Voters can mark, verify, and cast their ballot or other associated cast vote record, without assistance from others.

Principle 7: MARKED, VERIFIED, AND CAST AS INTENDED

Ballots and vote selections are presented in a perceivable, operable, and understandable way and can be marked, verified, and cast by all voters.

7.1 - The default voting system settings present a ballot usable for the widest range of voters, and voters can adjust settings and preferences to meet their needs.

7.2 - Voters and election workers can use all controls accurately, and voters have direct control of all ballot changes and selections.

7.3 - Voters can understand all information as it is presented, including instructions, messages from the system, and error messages.

Principle 8: ROBUST, SAFE, USABLE, AND ACCESSIBLE

The voting system and voting processes provide a robust, safe, usable, and accessible experience.

8.1 - The voting system's hardware, software, and accessories are robust and do not expose users to harmful conditions.

8.2 - The voting system meets currently accepted federal standards for accessibility.

8.3 - The voting system is evaluated for usability with a wide range of representative voters, including those with and without disabilities.

8.4 - The voting system is evaluated for usability with election workers.

Principle 9: AUDITABLE

The voting system is auditable and enables evidence-based elections.

9.1 - An error or fault in the voting system software or hardware cannot cause an undetectable change in election results.

9.2 - The voting system produces readily available records that provide the ability to check whether the election outcome is correct and, to the extent possible, identify the root cause of any irregularities.

9.3 - Voting system records are resilient in the presence of intentional forms of tampering and accidental errors.

9.4 - The voting system supports efficient audits

Principle 10: BALLOT SECRECY

The voting system protects the secrecy of voters' ballot selections.

10.1 - Ballot secrecy is maintained throughout the voting process.

10.2 - The voting system does not contain nor produce records, notifications, information about the voter or other election artifacts that can be used to associate the voter's identity with the voter's intent, choices, or selections.

Principle 11: ACCESS CONTROL

The voting system authenticates administrators, users, devices, and services before granting access to sensitive functions.

11.1 - The voting system enables logging, monitoring, reviewing, and modifying of access privileges, accounts, activities, and authorizations.

11.2 - The voting system limits the access of users, roles, and processes to the specific functions and data to which each entity holds authorized access.

11.3 - The voting system supports strong, configurable authentication mechanisms to verify the identities of authorized users and includes multi-factor authentication mechanisms for critical operations.

11.4 - The voting system's default access control policies enforce the principles of least privilege and separation of duties.

11.5 - Logical access to voting system assets are revoked when no longer required.

Principle 12: PHYSICAL SECURITY

The voting system prevents or detects attempts to tamper with voting system hardware.

12.1 - The voting system supports mechanisms to detect unauthorized physical access.

12.2 - The voting system only exposes physical ports and access points that are essential to voting operations.

Principle 13: DATA PROTECTION

The voting system protects data from unauthorized access, modification, or deletion.

13.1 –The voting system prevents unauthorized access to or manipulation of configuration data, cast vote records, transmitted data, or audit records.

13.2 - The source and integrity of electronic tabulation reports are verifiable.

13.3 - All cryptographic algorithms are public, well-vetted, and standardized.

13.4 - The voting system protects the integrity, authenticity, and confidentiality of sensitive data transmitted over all networks.

Principle 14: SYSTEM INTEGRITY

The voting system performs its intended function in an unimpaired manner, free from unauthorized manipulation of the system, whether intentional or accidental.

14.1 - The voting system uses multiple layers of controls to provide resiliency against security failures or vulnerabilities.

14.2 - The voting system limits its attack surface by avoiding unnecessary code, data paths, connectivity, and physical ports, and by using other technical controls.

14.3 - The voting system maintains and verifies the integrity of software, firmware, and other critical components.

14.4 - Voting system software updates are authorized by an administrator prior to installation.

Principle 15: DETECTION AND MONITORING

The voting system provides mechanisms to detect anomalous or malicious behavior.

15.1 - Voting system equipment records important activities through event logging mechanisms, which are stored in a format suitable for automated processing.

15.2 - The voting system generates, stores, and reports all error messages as they occur.

15.3 - The voting system is designed to protect against malware.

15.4 - A voting system with networking capabilities employs appropriate, well-vetted modern defenses against network-based attacks, commensurate with current best practice.

Principle 1
High Quality Design

HIGH QUALITY DESIGN

The voting system is designed to accurately, completely, and robustly carry out election processes.

1.1 - The voting system is designed using commonly-accepted election process specifications.

1.2 - The voting system is designed to function correctly under real-world operating conditions.

1.3 - Voting system design supports evaluation methods enabling testers to clearly distinguish systems that correctly implement specified properties from those that do not.

Principle 1
HIGH QUALITY DESIGN

The voting system is designed to accurately, completely, and robustly carry out election processes.

The requirements for Principle 1 and its guidelines include functional requirements for election definition and preparation through all voting processes concluding with closing of the polls, tabulating, and reporting. The requirements deal with how voting systems are designed to operate during election processes, including limits for stress and volume. Other principles provide more detailed requirements in other areas including accessibility, security, and usability.

The requirements for **Guideline 1.1** are arranged into sections by election process with requirements containing the basic core requirements for conducting an election:

1 – Election definition which deals with the capabilities of the voting system to define an election, that is, manage items such as election districts, contests, candidates, and to define ballots for the election that may be specific to various combinations or splits of precincts. Support for the specifications described in the NIST SP 1500-100 common data format (CDF) is required for imports and exports.

2 – Equipment setup which deals with capabilities of the voting system to configure and verify correctness of devices before opening the polls. Logic and accuracy (L&A) testing is covered here, as well as new requirements to check that cast vote records (CVR) are created properly and that any encoded data such as barcodes is accurately recorded.

3 - Opening the polls which deals with capabilities of the voting system to ensure that the voting system is properly configured so that polls can be opened.

4 - Ballot activation which deals with functions needed to activate the ballot for a voter. If ballot activation occurs on an electronic pollbook, one cannot test and verify whether these requirements are satisfied unless the entire pollbook is also tested.

5 - Casting which deals with the capabilities of the voting system to enable a voter to cast a ballot. The requirements deal with capabilities needed for common vote variations, ballot measures, and write-ins.

6 - Recording voter choices which deals with casting ballots and how equipment will handle ballots as they are cast, including the processes involved in recording votes in cast vote records. It mandates recording the selected contest options, and other information needed for linking the CVR with the device that is creating the CVRs and for auditing.

7 – Ballot handling for scanners which deals with functions that scanners will provide, including separating ballots for various reasons, for example, because of write-ins on manually-marked paper ballots and handling mis-fed ballots. It deals with the behavior of batch-fed scanners and voter-facing scanners when scanning ballots that need manual handling or inspection, such as for write-ins or unreadable ballots.

8 – Closing the polls which deals with exiting the voting mode (closing the polls), that is, stopping voting and preventing further voting. This applies to those systems located at a remote location such as the polling place.

9 – Tabulation which deals with how tabulation processes will handle voting methods, including those methods used most commonly across the United States.

10 - Reporting results which deals with the need for the voting system to have the capability to create all required precinct post-election reports. This includes recording ballots such as absentee ballots and Uniformed and Overseas Citizens Absentee Voting Act (UOCAVA) ballots.

The requirements for **Guideline 1.2** cover how a voting system is designed to function correctly under real-world operating conditions. They address:

- **Reliability** – the failure rate benchmark for reliability, the need to protect against a single point of failure, and the need for systems to withstand the failure of input and storage devices.
- **Accuracy** – the need to satisfy integrity constraints for accuracy, to achieve the required end-to-end accuracy benchmark, and the ability to reliably detect marks on the ballot.
- **Mid-feed rate** – which treats all misfeeds, such as multiple feeds, jams, and ballot rejections collectively as "misfeeds" and the need to meet the misfeed rate benchmark.
- **Stress** – the ability to respond gracefully to all stresses of the system's limits.
- **Election volume** –the ability to handle realistic volume of activities in normal use throughout an entire election process.

The requirements for **Guideline 1.3** cover how voting system design supports evaluation methods that enable testers to distinguish system that correctly implement specified properties from those that do not. They include:

- **Identifiability** – so testers can clearly identify the full set of basic and compound elements of the system.
- **System configuration processes**– so testers can understand how particular configurations of process and technology are formed to produce a final working system.
- **Observable configurations** – so testers can detect plausible observational tools and techniques to observe signs of the system configurations.
- **Identifiable resolution limits** – so testers can determine how well the observational tools and techniques can detect and distinguish each type of element in a system configuration.

- **Observational noise and consequences** – so testers can determine what sources of noise will arise from observing a system configuration and be able to map observable signs of those configurations.
- **Performance criteria** – so testers can state criteria the enable them to unambiguously decide whether an observed configuration exhibits intended properties.
- **Evaluation methods** – so testers can derive, construct and execute plausible evaluation methods that can:
    - Observe system configurations using observation tools and techniques
    - Decide whether a configuration has satisfied the performance criteria.
    - Report the findings.

1.1 – The voting system is designed using commonly-accepted election process specifications.

1.1.1 – Election definition

1.1.1-A – Election definition

An election definition must provide the information necessary to hold an election, including accurate information on election districts, contests, candidates, and ballot style information, along with the number of allowable votes for each contest and related rules for voting and tabulating the results.

Discussion

This requirement and its sub-requirements deal with the processes involved in election definition, including ballot definition and layout. It includes capability to:

- import election definition data that can be stored in external databases, and
- export the same data.

It includes the most commonly used voting methods in the United States, including for write-ins, ballot questions, straight party voting, N-of-M contests, cumulative voting contests, proportional voting contests, and ranked choice voting contests.

1.1.1-B – Election definition details

The election definition function must be capable of importing, defining, and maintaining:

1. contests and their associated labels and instructions
2. candidate names and their associated labels
3. ballot measures and their associated text

Discussion

Labels means any headers, footers, or other text that appears on the ballot along with the contest or candidate's name.

External reference:	NIST 1500-100 CDF
Related requirements	1.1.1-Z – Data inputs and outputs

1.1.1-C – Define political geographies

An election definition must clearly describe the political geographies where the list of contests varies between subdivisions. The political geographies include:

1. election districts, including Congressional, state government, and local government that may overlap each other
2. county, city, town and township jurisdictions
3. precincts, splits, and combinations of precincts
4. user-defined geographies

Discussion

User-defined geographies could include non-election districts such as mosquito abatement districts.

1.1.1-D – Serve multiple or split precincts and election districts

An election definition must describe election districts and precincts in such a way that a given polling place may serve:

1. two or more election districts
2. combinations of precincts and split precincts

Discussion

This requirement addresses the capability of precinct devices to be flexible in accommodating multiple ballot styles depending on the political geography being served by a polling place.

1.1.1-E – Identifiers

An election definition must enable election officials (EOs) to associate multiple identifiers that can be cross-referenced with each other for administrative subdivisions, election districts, contests, and candidates, including for:

1. locally-defined identifiers
2. state-wide-defined identifiers
3. Open Civic Data Identifiers (OCD-IDs)

Discussion

This is based on the need to support cross-referencing of statewide identifier schemes or schemes such as OCD-IDs with those used on a more local level.

1.1.1-F – Definition of parties and contests

An election definition must allow for:

1. the definition of political parties and indicate the affiliation or endorsements of each contest option
2. information on both party-specific and non-party-specific contests, with the capability to include both contests on the same ballot
3. contests that include ballot positions with write-in opportunities

1.1.1-G – Voting methods

An election definition must enable election officials to define and identify contests, contest options, candidates, and ballot questions using all voting methods indicated in the manufacturer-provided implementation statement.

1. For N-of-M contests, an election definition must be capable of defining contests where the voter is allowed to choose up to a specified number of contest options from a list of options.
2. For ballot questions, an election definition must include the ability to create ballot questions where the voter is allowed to vote yes or no on a question.
3. For ballot questions, an election definition must include the ability to create ballot questions where the voter is allowed to vote on one or more from a list of possible choices on a question.
4. For the cumulative voting method, an election definition must include the ability to create ballot questions where the voter is allowed to allocate up to a specified number of votes over a list of contest options, possibly giving more than one vote to a given option.
5. For the proportional voting method, an election definition must include the ability to create ballot questions where the candidate gets the number of votes equal to those allowed divided by number of selections.
6. For the ranked choice voting method, an election definition must include the ability to create ballot questions where the voter is allowed to rank contest options in order of preference, as first choice, second choice, etc.
7. For the cross-party endorsement voting method, an election definition must include the ability to create ballot questions about the necessary straight party contest and record the endorsements made by each party in the election definition. This supports gathering and recording votes for the slate of contest options endorsed by a given

political party when a given contest option is endorsed by two or more different political parties.

1.1.1-H – Election definition accuracy

An election definition must record the election contests, contest options, issues, and political and administrative subdivisions exactly as defined by EOs.

1.1.1-I – Voting options accuracy

An election definition must record the options for casting and recording votes exactly as defined by EOs.

1.1.1-J – Confirm recording of election definition

An election definition must check and confirm that its data is correctly recorded to persistent storage.

Discussion

"Persistent storage" includes storage systems such as nonvolatile memory, hard disks, and optical disks.

1.1.1-K – Election definition distribution

An election definition must provide for generating master and distributed copies of election definitions as needed to configure each voting device in the system.

1.1.1-L – Define ballot styles

An election definition must enable EOs to define ballot styles.

1.1.1-M – Auto-format

An election definition must be capable of automatically formatting ballots according to jurisdictional requirements for office and contest options qualified to be placed on the ballot for each political subdivision and election district.

1.1.1-N – Include contests

An election definition must provide for the inclusion in a given ballot style of all contests in which the voter would be entitled to vote.

1.1.1-O – Exclude contests

An election definition must provide for the exclusion from a given ballot style of any contest in which the voter would be prohibited from voting because of place of residence or other administrative criteria.

Discussion

In systems supporting primary elections, this would include the exclusion of party-specific contests that voters in a particular political party are not eligible to vote in.

1.1.1-P – Nonpartisan formatting

An election definition must support the uniform allocation of space and fonts used for each office, contest option, and contest so the voter does not perceive that one contest option is preferred over any other.

1.1.1-Q – Jurisdiction-dependent content

An election definition must enable EOs to add jurisdiction-dependent text, line art, logos, and images to ballot styles.

1.1.1-R – Primary elections, associate contests with parties

When implementing primary elections, an election definition must support the association of different contests with different political parties.

1.1.1-S – Ballot rotation

When implementing ballot rotation, an election definition must support producing rotated ballots or activating ballot rotation functions in vote-capture devices by including relevant metadata in distributed election definitions and ballot styles.

Related requirement: 1.1.5-I – Ballot rotation for contest options

1.1.1-T – Ballot configuration in combined or split precincts

When implementing combined or split precincts, an election definition must include the ability to create distinct ballot configurations for voters from two or more election districts that are served by a given polling place.

1.1.1-U – No advertising

The ballot presented to the voter must not display or link to any advertising or commercial logos of any kind, whether public service, commercial, or political.

1.1.1-V – Ballot style distribution

An election definition must include the option to generate master and distributed copies of ballot styles as needed to configure each voting device in the system.

1.1.1-W – Ballot style identification

An election definition must generate codes or marks as needed to uniquely identify the ballot style associated with any ballot.

Discussion

In paper-based systems, identifying marks would appear on the actual ballots. Ballot marking devices (BMDs) would make internal use of unique identifiers for ballot styles but would not necessarily present these where the voter would see them. In both cases, the identifying mark also could be recorded in the cast vote record.

1.1.1-X – Retaining, modifying, reusing definitions

An election definition must support retaining, modifying, and reusing general districting or precinct definitions and ballot formatting parameters within the same election and from one election to the next.

1.1.1-Y – Ballot style protection

An election definition must prevent unauthorized modification of any ballot styles.

Discussion

See security requirements for information on techniques to prevent unauthorized modifications.

1.1.1-Z – Data inputs and outputs

An election definition must support NIST 1500-100 CDF specifications for election programming data inputs and outputs, including for:

1. import of election programming data
2. export of election programming data
3. reports of election programming data to ensure the data is inspected and verified

Discussion

Item 1 concerns import of pre-election data such as for identification of political geography, contest, candidate, ballot data, and other pre-election information used to setup an election and produce ballots. Items 2 and 3 refer to exporting and reporting the pre-election data from the election definition device so that it can be checked for accuracy or exchanged as needed.

External reference:	NIST 1500-100 CDF
Related requirements	1.1.1-B – Election definition details

1.1.2 – Equipment setup

1.1.2-A – Equipment setup

The voting system must provide the capability to verify that:

1. all voting devices are properly prepared for an election using real world scenarios and collect data that verify equipment readiness
2. all system equipment is correctly installed and interfaced
3. hardware and software function correctly

Discussion

This requirement and its sub-requirements deal with equipment setup prior to the election. They deal primarily with logic and accuracy testing (L&A), whose purpose is to detect malfunctioning and misconfigured devices before polls are opened. Election personnel conduct equipment and system readiness tests before an election to:

- ensure that the voting system functions properly,
- confirm that system equipment has been properly integrated, and
- obtain equipment status and readiness reports.

The intent is that the voting system and devices be configured so real-world configuration scenarios will be supported and testable.

1.1.2-B – Built-in self-test and diagnostics

The voting system must include built-in measurement, self-testing, and diagnostic software and hardware for monitoring and reporting the system's status and degree of operability.

1.1.2-C – Verify proper preparation of ballot styles

An election definition must allow for EOs to test that ballot styles and programs have been properly prepared.

1.1.2-D – Verify proper installation of ballot styles

The voting system must include the capability to automatically verify that the software and ballot styles have been properly selected and installed in the equipment and can immediately notify an EO of any errors.

Discussion

At a minimum, notification means an error message, a log entry, and a "failed" result on this portion of the L&A test. Examples of detectable errors include use of software or data intended for a different type of device or operational failures in transferring the software or data.

1.1.2-E – Verify compatibility between software and ballot styles

The voting system must include the ability to automatically verify that software correctly matches the ballot styles that it is intended to process and immediately notify an EO of any errors.

Discussion

At a minimum, notification means an error message, a log entry, and a "failed" result on this portion of the L&A test.

1.1.2-F – Test ballots

The voting system must allow for EOs to submit test ballots for use in verifying the integrity of the system.

1.1.2-G – Test all ballot positions

Scanners must allow for testing that uses all potential ballot positions as active positions.

1.1.2-H – Test Cast Vote Records

The voting system must include the ability to verify that CVRs are created and tabulated correctly by permitting EOs to compare the created CVRs with the test ballots.

Discussion

This requires providing a capability such as an export of CVRs and a tabulated summary that can be compared manually against their test ballot counterparts.

1.1.2-I – Test codes and images

The voting system must include the ability to verify that any encoded version or images of voter selections on a ballot are created correctly.

Discussion

The purpose is to ensure that an encoded version of voter selections such as provided by a ballot marking device (BMD) using QR codes contains the voter's selections exactly as made. It will also ensure that any image of the ballot made by a scanner correctly matches the ballot. BMDs may encode other items as appropriate in codes, for example, ballot style ID.

1.1.2-J – Testing calibration

Scanners must support the use of test ballots to test the calibration of the paper-to-digital conversion (such as the calibration of optical sensors, the density threshold, and the logical reduction of scanned images to binary values, as applicable).

1.1.2-K – Ballot marker readiness

Ballot marking must allow for a way to verify that the ballot marking mechanism is properly prepared and ready to use.

1.1.2-L – L&A testing, no side-effects

Logic and accuracy testing functions must introduce no lasting effects on operation during the election other than:

1. audit log entries
2. status changes to note that the tests have been run with a successful or failed result
3. separate storage of test results
4. changes in the protective counter or life-cycle counter (if the device has one)
5. normal wear and tear

Discussion

Subsequent requirements preclude the device from actually serving in the election unless these tests are successful. Apart from that safeguard, it should be impossible (by design) for the L&A testing to have any influence on the operation of the device during the election or on the results that are reported for the election. Most notably, election results can never include any test votes that were counted during L&A testing.

1.1.2-M – Status and readiness reports

The voting system must provide the capability to produce status and equipment readiness reports.

Discussion

These reports typically are generated during pre-voting logic and accuracy testing.

1.1.2-N – Pre-election reports

The voting system must provide the capability to produce a report that includes:

1. The allowable number of votes in each contest
2. The counting logic (for example, N-of-M, cumulative, or ranked choice) that is used for each contest
3. The inclusion or exclusion of contests as the result of precinct splits
4. Any other characteristics that may be peculiar to the jurisdiction, the election, or the precincts
5. Manual data maintained by election personnel
6. Samples of all final ballot styles
7. Ballot preparation edit listings

Discussion

The purpose of this requirement is for sanity checks of the election configuration. Previous requirements mandate support for the NIST 1500-100 CDF specification.

External reference: NIST 1500-100 CDF specification

1.1.2-O – Readiness reports for each polling place

Readiness reports must include at least the following information for each polling place:

1. The election's identification data
2. The identification of the precinct and polling place
3. The identification of all voting devices deployed in the precinct
4. The identification of all ballot styles used in that precinct
5. Confirmation that no hardware or software failures were detected during setup and testing, or a record of those that occurred

6. Confirmation that all vote-capture devices are ready for the opening of polls, or identification of those that are not

1.1.2-P – Readiness reports, precinct tabulation

Readiness reports must include the following information for each voter-facing scanner or other precinct reporting device:

1. The election's identification data
2. The identification of the precinct and polling place
3. The identification of the voter-facing scanner
4. The contents of each active contest option register at all storage locations
5. Confirmation that no hardware or software failures were detected during setup and testing, or a record of those that occurred
6. Any other information needed to confirm the readiness of the equipment and to accommodate administrative reporting requirements

1.1.2-Q – Readiness reports, central tabulation

Readiness reports must include the following information for each batch-fed scanner or other central reporting device:

1. The election's identification data
2. The identification of the tabulator
3. The identification of all ballot styles used in the system extent
4. The contents of each active contest option register at all storage locations
5. Confirmation that no hardware or software failures were detected during setup and testing, or a record of those that occurred
6. Any other information needed to confirm the readiness of the equipment and to accommodate administrative reporting requirements

1.1.2-R – Readiness reports, public network test ballots

Systems that send ballots over a public network must provide a report of test ballots that includes:

1. the number of test ballots sent

2. when each test ballot was sent
3. the identity of the machine from which each test ballot was sent
4. the specific votes contained in the test ballots

1.1.3 – Opening the Polls

1.1.3-A – Opening the polls

The voting system must provide functions to enter and exit a mode in which voting is permitted.

Discussion

This and following requirements cover the process of enabling voting to occur by placing the voting system in a voting mode.

1.1.3-B – Verify L&A performed

The voting system must provide internal test or diagnostic capabilities to verify that the applicable tests specified in the equipment setup requirements have been successfully completed.

Discussion

When an L&A test is conducted, that test will indicate whether any aspects of the test were successful or failed.

1.1.3-C – Prevent opening the polls

The voting system must not enter the voting mode unless and until the readiness test has been performed successfully and any steps necessary to isolate test data from election data have been performed successfully.

Discussion

If a device has not been tested, has failed its L&A test, or the test data have not been isolated (that is, test votes could end up being included in election results), then the device is not ready for use in the election.

1.1.3-D – Non-zero totals

Tabulation must not enter the voting mode unless and until the L& A test has been performed successfully, any steps necessary to isolate test data from election data have been performed successfully, and all vote counters have been zeroed. An attempt to open polls with non-zero totals:

1. must be recorded in the audit log
2. an EO must be clearly notified of the event

Discussion

Jurisdictions that allow early voting before the traditional election day should note that a distinction is made between the opening and closure of polls, which can occur only once per election, and the suspension and resumption of voting between days of early voting. The open-polls operation, which requires zeroed counters, is performed only when early voting commences; the resumption of voting that was suspended overnight does not require that counters be zeroed again.

1.1.3-E – Scanners and ballot marking devices - verify activation

Scanners and ballot marking devices must include a means of verifying that they have been correctly activated and are functioning properly.

1.1.3-F – Scanners and ballot marking devices - enter voting mode

Scanners and ballot marking devices must provide designated functions for entering voting mode. They must include:

1. access control to prevent the inadvertent or unauthorized activation of the poll-opening function.
2. a means of enforcing the execution of poll-opening steps in the proper sequence if more than one step is required.
3. a means of verifying that the system has been correctly activated.

1.1.4 - Ballot Activation

This section deals with functions needed to activate the ballot for a voter. If ballot activation occurs on an electronic pollbook, one cannot test and verify whether these requirements are satisfied unless the entire pollbook is also tested.

1.1.4-A – Ballot activation

The voting system must support ballot activation.

1.1.4-A.1 – One cast ballot per session

The voting system must enable election workers either to initiate or to provide the voter with the credentials sufficient to initiate a voting session in which the voter may cast or print at most one ballot.

Discussion

A voting session on a BMD may end with the printing of the voter's contest selections, that is, scanning contest selections need not be considered part of the voting session.

1.1.4-A.2 – Contemporaneous record

The voting system must create contemporaneous records of the credentials issued to a voter. The record, once made, will not be able to be modified by the voting system.

Discussion

The voting system creates a record at the time when credentials are issued to voters so that the records collected can be compared to the number of ballots voted. This may be done if the activation device prints a record or by using a paper pollbook.

1.1.4-A.3 – Control ballot configuration

The voting system must enable election workers to control the ballot configurations made available to the voter, whether presented in printed form or electronic display, so that each voter is permitted to record votes only in contests in which that voter is authorized to vote. The voting system must:

1. activate all portions of the ballot the voter is entitled to vote on.
2. disable all portions of the ballot the voter is not entitled to vote on.
3. enable the selection of the ballot configuration that is appropriate to the party affiliation declared by the voter in a primary election.

Discussion

For an electronic display, poll workers control the ballot configuration using an activation device and issuing credentials. In paper-based systems, open primaries have sometimes been handled by printing a single ballot style that merges the contests from all parties, instructing the voter to vote only in the contests applicable to a single party, and rejecting or discarding votes that violate this instruction. To use that approach on a paper-based BMD would violate this requirement.

1.1.5 - Casting

1.1.5-A – Voting methods when casting

The voting system must record all individual contest options for each contest using all voting methods indicated for them in the implementation statement.

Discussion

This requirement and its sub-requirements deal with general support for casting ballots using the most common voting methods used in the United States. (Voting methods are otherwise known as voting variations.) When a ballot is cast, the voting system will create an electronic record of the voter's selections, that is, a cast vote record. The cast vote record need not include those contest options not selected by the voter; their absence in the cast vote record indicates their non-selection.

1.1.5-B – N-of-M voting

For the N-of-M voting method, the voting system must be capable of gathering and recording votes in contests where the voter is allowed to choose up to a specified number of contests from a list of contest options.

1.1.5-C – Yes/no measures and multiple-choice measures

For ballot measures, the voting system must be capable of gathering and recording votes in contests where the voter is allowed to:

1. vote yes or no on a measure
2. vote for selections from a list of choices

1.1.5-D – Indicate party affiliations and endorsements

The voting system must be capable of indicating the affiliation or endorsements of each contest option.

1.1.5-E – Closed primaries

For closed primaries, the voting system must be capable of gathering and recording votes within a voting process that:

1. assigns different ballot styles depending on the registered political party affiliation of the voter
2. supports both party-specific and non-party-specific contests

1.1.5-F – Open primaries

For open primaries, the voting system must be capable of gathering and recording votes within a voting process that assigns different ballot styles depending on the political party chosen by the voter at the time of voting and supports both party-specific and non-party-specific contests.

Discussion

In paper-based systems, open primaries have sometimes been handled by printing a single ballot style that merges the contests from all parties, instructing the voter to vote only in the contests applicable to a single party, and rejecting or discarding votes that violate this instruction.

1.1.5-G – Write-ins

The voting system must record the voter's write-in of candidates whose names do not appear on the ballot and record as many write-in votes as the voter is allowed.

1.1.5-H – Write-in reconciliation

The voting system must be capable of gathering and recording votes within a voting process that allows for reconciliation of aliases and double votes resulting from write-ins.

Discussion

Reconciliation of aliases means allowing EOs to declare two different spellings of a candidate's name to be equivalent (or not), as could happen from write-ins. Reconciliation of double votes means handling the case where, in an N-of-M contest, a voter has attempted to cast multiple votes for the same candidate using the write-in mechanism.

1.1.5-I – Ballot rotation for contest options

For ballot rotation, the voting system must be capable of gathering and recording votes when the ordering of contest options in ballot positions within each contest is variable in such a manner that does not show bias to any contest option.

Discussion

The intent is to ensure that the manner in which the rotation algorithm works does not show bias towards any candidate, that is, all contest options appear equally in rotated positions to the extent possible.

1.1.5-J – Straight party voting

For straight party voting, the voting system must be capable of gathering and recording votes for a special contest in which the selection of a political party implies votes for the contest options endorsed by that party in all straight-party contests on the ballot.

1.1.5-K – Cross-party endorsement

For cross-party endorsement, the voting system must be capable of gathering and recording straight-party votes when a given contest option is endorsed by two or more different political parties.

1.1.5-L – Precinct splits

The voting system must be capable of gathering and recording votes in a polling place where there are distinct ballot styles for voters from two or more political geographies.

1.1.5-M – Cumulative voting

For cumulative voting, the voting system must be capable of gathering and recording votes in contests where the voter is allowed to allocate up to a specified number of votes over a list of contest options, possibly giving more than one vote to a given contest option.

1.1.5-N – Ranked choice voting

For ranked choice voting, the voting system must be capable of gathering and recording votes in contests where the voter is allowed to rank contest options in a contest in order of preference, as first choice, second choice, etc.

1.1.5-O – Recallable ballots

See Section 10.2.1 for requirements to identify recallable ballots.

Discussion

Recallable ballots that are scanned and for which a CVRs have been created, cannot be recalled without being able to remove a ballot's corresponding CVR. Thus, there is a need to know the voter, the voter's ballot, and the corresponding CVR. This presents a potential voter privacy issue. See Section 10.2.1 for requirements that deal with this issue.

1.1.5-P – Review-required ballots

The voting system must be capable of gathering and recording votes within a voting process that requires certain ballots to be flagged or separated for review.

Discussion

In some systems and jurisdictions, all ballots containing write-in votes require flagging or separation for review. Support for this indicates that the system can flag or separate ballots in this manner and include the results of the review in the reported totals. Other reasons for which ballots are flagged or separated are jurisdiction-dependent.

1.1.6 – Recording Voter Choices

1.1.6-A – Casting and recording

All systems must support casting a ballot and recording each vote precisely as indicated by the voter, subject to the rules of the election jurisdiction.

1.1.6-B – Secure ballot boxes

Voting systems that include paper ballots must include secure receptacles for holding cast ballots.

1.1.6-C – Prevent counter overflow

When the voting system can no longer accept another ballot without the potential of overflowing a vote counter or otherwise compromising the integrity of the counts, it must notify the user or operator and cease to accept new ballots.

Discussion

Assuming that the counter size is large enough that the value will never be reached is not an adequate safeguard. Systems are required to detect and prevent an impending overflow condition. This requirement is in response to past issues in which devices would use up available memory but give no warning and continue to permit voters to cast ballots.

1.1.6-D – Ballot orientation

Ballot marking devices that use pre-printed ballots must either:

1. correctly mark pre-printed ballots regardless whether they are loaded upside down, right side up, forward, or reversed
2. detect and reject pre-printed ballots that are oriented incorrectly

1.1.6-E – Records consistent with feedback to voter

All CVRs and logs must be consistent with the feedback they give to the voter.

Discussion

This does not mean that every message displayed to the voter during an interactive session will be included in every CVR or log. It means that the records and the interactive messages will not be in conflict with one another. For example, it is not permissible to show a vote for candidate X on the display, and then record a vote for candidate Y.

1.1.6-F – Record contest selection information

The voting system must record contest selection information in the CVR that includes:

1. all contest selections made by the voter for all supported vote variations
2. positions on the ballot associated with each contest selection made by the voter, including when multiple selections are permitted, if applicable

1.1.6-G – Record write-in information

The voting system must record write-in information in the CVR that includes:

1. identification of write-in selections made by the voter
2. the text of the write-in, when using a BMD or other device that marks the ballot for the voter
3. an image or other indication of the voter's write-in markings
4. an indication whether the write-in has been adjudicated and constitutes a tabulatable vote
5. the total number of write-ins in the CVR

1.1.6-H – Record election and contest information

The voting system must record additional contest information in the CVR that includes:

1. identification of all contests in which voter has made a contest selection
2. identification of the contest vote method including number of votes allowed in the contest and the maximum number of valid contest selections
3. identification of all overvoted and undervoted contests
4. the number of write-ins recorded for the contest
5. identification of the party for partisan ballots or partisan contests

Discussion

For identification of the party, a ballot in a partisan primary may in some cases contain contests for different parties. Thus, an indication as to whether the contest is partisan is required.

1.1.6-I – Record ballot selection override information

Scanners, if tabulating voter selections differently than as marked due to election or contest rules in effect, must record information in the CVR that includes:

1. identification of the original ballot selections made by the voter
2. identification of the changed voter selections
3. identification of the reasons for the changes

Discussion

When marking a ballot by hand, a voter may vote in contests in which the voter is not allowed to make contest selections. For example, a voter may elect to vote straight party, but then make contest selections in contests anyway. Election or contest rules may cause a scanner to invalidate the contest markings or require other actions.

1.1.6-J – Record detected mark information

Scanners must record, for each mark detected on the ballot, information in the CVR that includes:

1. indications of marginal marks that are made by the voter or that are due to imperfections on the ballot
2. mark quality information for each detected mark

Discussion

This applies to contest selections recognized as valid as well as to marginal marks or other detected facets of contest selection positions that are detected by the scanner. For example, a crease in the

ballot may be detected by the scanner as a marginal mark. The measurement of mark quality may be specific to manufacturer and model of scanner.

1.1.6-K – Record audit information

The voting system must be capable of recording audit-related information in the CVR or collection of CVRs as they are created, that includes:

1. identification of the specific creating device such as a serial number
2. identification of the geographical location of the device
3. Identification of the ballot style corresponding to the CVR
4. identification of the corresponding voted ballot
5. for multi-sheet ballots, identification of the individual sheet corresponding to the CVR, along with the identification of the ballot style
6. identification of the batch containing the corresponding voted ballot, when applicable
7. sequence of the corresponding voted ballot in the batch, when applicable

Discussion

Item 4 can be satisfied by printing a unique ID on the ballot as it is scanned and including that ID in the corresponding CVR.

Item 5 ensures that every sheet of a multi-sheet ballot contains the sheet number as well as the ballot style ID. This way, a ballot style ID could be defined to include all sheets, or each sheet could be defined with a unique ballot style.

Items 6 and 7 are necessary when ballot batching is in effect.

1.1.7 – Ballot handling for paper ballot scanners

1.1.7-A – Ballot handling functions for scanners

Scanners must provide features for handling ballots when they are scanned individually using voter-facing scanners or scanned in batches using batch-fed scanners.

1.1.7-B – Detect and prevent ballot style mismatches

All voting systems must detect ballot style mismatches and prevent votes from being tabulated or reported incorrectly due to a mismatch.

Discussion

For example, if the ballot styles loaded on a scanner disagree with the ballot styles that were used by vote-capture devices, the system will raise an alarm and prevent the incorrect ballot styles from being used during tabulation. Otherwise, votes could be ascribed to the wrong contest options.

Such a mismatch should have been detected and prevented in L&A testing but if it was not, it needs to be detected and prevented before tabulation begins.

1.1.7-C – Detect and reject ballots that are oriented incorrectly

Scanners must do one of the following:

1. correctly count ballots regardless of whether they are fed upside down, right side up, forward, or reversed
2. detect and reject ballots that are oriented incorrectly

1.1.7-D – Ballot separation when batch feeding

In response to unreadable ballots, write-ins, and other designated conditions, batch-fed scanners must do one of the following:

1. out stack the ballot (that is, divert to a stack separate from the ballots that were normally processed)
2. stop the ballot reader and display a message prompting the EO to remove the ballot
3. mark the ballot with an identifying mark to facilitate its later identification

Discussion

The requirement to separate ballots containing write-in votes is not applicable in systems in which a BMD encodes write-in votes in machine-readable form and a scanner generates individual tallies for all written-in candidates automatically. Separation of ballots containing write-in votes is only necessary in systems that require the allocation of write-in votes to specific candidates to be performed manually.

1.1.7-E – Overvotes, undervotes, blank ballots

Voter-facing scanners must provide a capability that can be activated by EOs to stop the scanning and display a message to the EO to remove and correct the ballot in response to the following ballot conditions:

1. ballots containing overvotes in a designated contest
2. ballots containing undervotes in a designated contest

3. ballots containing contests that were not voted
4. blank ballots

1.1.7-F – Write-ins

When scanning a ballot containing a write-in vote, voter-facing scanners must segregate the ballot in a manner that facilitate its later identification.

Discussion

The requirement to separate ballots containing write-in votes is not applicable in systems in which a BMD encodes write-in votes in machine-readable form and a scanner generates individual tallies for all written-in candidates automatically. Separation of ballots containing write-in votes is only necessary in systems that require the allocation of write-in votes to specific candidates to be performed manually.

1.1.7-G – Ability to clear misfeed

If multiple feed or misfeed (jamming) occurs, a batch-fed scanner must:

1. halt in a manner that permits the operator to remove the ballots causing the error and reinsert them in the input hopper (if unread) or insert them in the ballot box (if read)
2. indicate whether or not the ballots causing the error has been read

Discussion

The second bullet deals with whether a CVR has been created for the ballots that jammed; EOs needs to know whether to re-feed the ballot.

1.1.7-H – Scan to manufacturer specifications

Scanners must detect marks made on paper ballots according to non-proprietary, published manufacturer specifications.

Discussion

Manufacturers will publish their specifications for detecting marks, and these specifications will be publicly available. Because voters may make any number of mistakes when marking a ballot, canners need to interpret the marks according to these published specifications as well as possible. Requirements in the Casting section require the manufacturer to include, in the CVR, an indication of mark quality for each detected mark.

1.1.7-I – Ignore unmarked contest option positions

Scanners must ignore (that is, not record as votes) unmarked contest option positions.

Discussion

"Unmarked" in this requirement means containing no marks of any kind other than those designed to be present as part of the ballot style. This includes extraneous perforations, smudges, folds, and blemishes in the ballot stock.

1.1.7-J – Accurately detect perfect marks

Scanners must detect marks that conform to manufacturer specifications.

1.1.7-K – Accurately detect imperfect marks

Scanners must detect a 1 mm thick line that:

1. is made with a #2 pencil that crosses the entirety of the contest option position on its long axis,
2. is centered on the contest option position
3. is as dark as can practically be made with a #2 pencil

Discussion

Different optical scanning technologies will register imperfect marks in different ways. Variables include:

- the size, shape, orientation, and darkness of the mark;
- the size, shape, orientation, and darkness of the mark;
- the location of the mark within the voting target;
- the wavelength of light used by the scanner;
- the size and shape of the scanner's aperture;
- the color of the ink;
- the sensed background-white and maximum-dark levels; and,
- the calibration of the scanner.

The mark specified in this requirement is intended to be less than 100 % perfect, but reliably detectable, that is, not so marginal as to bring the uncontrolled variables to the forefront. In plain language: scanning technologies may vary, but as a minimum requirement, all of them should be capable of reliably reading *this* mark.

1.1.7-L – Ignore extraneous marks outside contest option position

Scanners must not record as votes any marks, perforations, smudges, or folds appearing outside the boundaries of contest option positions.

1.1.7-M – Ignore extraneous marks inside voting targets

Scanners must not record as votes any imperfections in the ballot stock, folds, and similar insignificant marks appearing inside voting targets.

Discussion

Insignificant marks appearing inside voting targets can be detected as votes. This problem should be minimized.

1.1.7-N – Ignore hesitation marks

Scanners must not record hesitation marks and similar insignificant marks as votes.

Discussion

It may be possible to reliably detect reasonable marks and reliably ignore hesitation and other insignificant marks if the scanner is calibrated to a specific marking utensil or, when an image is made of the ballot, analysis of the image.

1.1.7-O – Marginal marks, no bias

The detection of marginal marks from manually-marked paper ballots must not show a bias.

Discussion

Bias errors are not permissible in any system. An example of bias would be if marginal marks in the first ballot position were detected differently than marginal marks in the second ballot position.

1.1.7-P – Repeatability

The detection of marginal marks from manually-marked paper ballots must be repeatable.

Discussion

It is difficult to have confidence in the equipment if consecutive readings of the same ballots on the same equipment yield dramatically different results. However, it is technically impossible to achieve repeatable reading of ballots containing marks that fall precisely on the sensing threshold.

1.1.8 – Closing the Polls

1.1.8-A – Closing the polls

The voting system must provide designated functions for exiting election mode and stopping voting.

Discussion

When voting is conducted across multiple days, for example, for early voting, these requirements are still applicable even though the election itself may not be over, with the exception of requirement 1.1.8-E – Prevent reopening polls, which deals with preventing, on election day, re-opening of the polls once they have been closed.

1.1.8-B – No voting when polls are closed

The voting system must prevent the further enabling, activation, marking, or casting of ballots by any device once the polls have closed.

Discussion

A BMD cannot prevent a voter from marking a paper ballot with a writing utensil after polls have closed. This needs to be prevented through procedures.

1.1.8-C – Poll closing integrity check

The voting system must provide an internal test that verifies that the prescribed closing procedure has been followed and that the device status is normal.

1.1.8-D – Report on poll closing process

The voting system must provide a means to produce a diagnostic test record that verifies the sequence of events and indicates that the poll closing process has been activated.

1.1.8-E – Prevent reopening polls

The voting system must prevent reopening of the polls once the poll closing has been completed for an election.

Discussion

For early voting conducted across multiple days, this requirement does not prevent reopening of the polls on the following day. This requirement is only applicable on the final day of election

1.1.9 – Tabulation

1.1.9-A – Voting methods when tabulating

Tabulation must support all voting methods indicated in the implementation statement.

1.1.9-B – N-of-M voting

For N-of-M voting, tabulation must be capable of tabulating votes, overvotes, and undervotes in contests where the voter is allowed to choose up to a specified number of contest options from a list of contest options.

1.1.9-C – Yes/no measure and multiple-choice measure

For yes/no measures and multiple-choice measures, tabulation must be capable of tabulating votes, overvotes, and undervotes in contests where the voter is allowed to:

1. vote yes or no on a measure
2. choose from a list of multiple choices on a measure

1.1.9-D – Recallable ballots

For recallable ballots, tabulation must be capable of tabulating votes, overvotes, and undervotes in contests where the decision whether to count a particular ballot is deferred until after election day.

1.1.9-E – Accept or reject recallable ballots individually

Tabulation must support the independent acceptance and rejection of individual recallable ballot.

Discussion

This is meant to rule out the mode of failure in which the IDs assigned to provisional ballots fail to be unique, rendering the system incapable of accepting one without also accepting the others with the same ID.

1.1.9-F – Accept or reject recallable ballots by category

Tabulation must support the acceptance and rejection of recallable ballots by category.

1.1.9-G – Primary elections

For primary elections, tabulation must be capable of keeping separate totals for each political party for the number of ballots read and counted.

Discussion

In paper-based systems, open primaries have sometimes been handled by printing a single ballot style that merges the contests from all parties and instructing the voter to vote only in the contests applicable to a single party. This approach requires additional logic in the tabulator to support rejecting or discarding votes that violate these special instructions, while the approach of assigning different ballot configurations to different parties does not. Support for the merged ballot approach is not required for a tabulator.

This requirement to separate by party applies only to the number of read ballots and counted ballots. It does not apply to contest option vote totals.

1.1.9-H – Write-ins

For write-ins, tabulation must be capable of tabulating votes for write-in candidates, with separate totals for each candidate.

1.1.9-I – Support write-in reconciliation

For write-ins, tabulation must be capable of tabulating votes within a voting process that allows for reconciliation of aliases and double votes.

Discussion

Reconciliation of aliases means allowing EOs to declare two different spellings of a candidate's name to be equivalent (or not). Reconciliation of double votes means handling the case where, in an N-of-M contest, a voter has attempted to cast multiple votes for the same candidate using the write-in mechanism.

1.1.9-K – Ballot rotation

Tabulation must be capable of tabulating votes when the ordering of contest options in ballot positions within each contest is variable.

Discussion

This simply means that ballot rotation will not impact the correctness of the count.

1.1.9-L – Straight party voting

Tabulation must be capable of tabulating straight party votes.

1.1.9-M – Tabulating straight party votes

A straight party vote must be counted as a vote in favor of all contest options endorsed by the chosen party in each straight-party-voting contest in which the voter does not cast an explicit vote.

Discussion

This requirement intentionally says nothing about what happens when there is both a straight party endorsed contest option and an explicit vote in a given contest (a straight party override). Jurisdictions may handle this in various ways, including to void the ballot or contest.

1.1.9-N – Cross-party endorsement

For cross-party endorsement, tabulation must be capable of tabulating straight-party votes when a given contest option is endorsed by two or more different political parties.

1.1.9-O – Precinct splits

Tabulation must be capable of tabulating votes for precinct splits or combinations of precincts.

1.1.9-P – Cumulative voting

For cumulative voting, tabulation must be capable of tabulating votes, overvotes, and undervotes in contests where the voter is allowed to allocate up to a specified number of votes over a list of contest options however they choose, possibly giving more than one vote to a given contest option.

1.1.9-Q – Ranked choice voting

For ranked choice voting, tabulation must be capable of determining the results of a ranked choice contest for each round of tabulation.

Discussion

This requirement is minimal. Since ranked choice voting is not currently in wide use, it is not clear what, other than the final result, will be computed.

1.1.10 – Reporting Results

1.1.10-A – Post-election reports

The voting system must have the capability to create precinct post-election reports.

1.1.10-B – Reporting device consolidation

When more than one vote-capture device or voter-facing scanner is used, it must be possible to consolidate the data contained in each unit into a single report for the polling place. If the consolidation of polling place data is done locally, the precinct reporting device needs to perform this consolidation in no more than 5 minutes per scanner.

Discussion

This requirement essentially requires precinct-based vote capture devices to be able to consolidate voting data for the purposes of issuing one consolidated report.

1.1.10-C – Reporting is non-destructive

The voting system must prevent data, including data in transportable memory, from being altered or destroyed by report generation.

Discussion

Appending an audit record reflecting the fact that a report has been generated is not considered an alteration.

1.1.10-D – Ballot and vote counts

The voting system must be capable of generating human-readable reports of the vote and ballot count, including the capability for:

1. alphanumeric headers
2. election, office, and issue text
3. alphanumeric entries generated as part of the audit record

Discussion

This requirement and its sub-requirements specify a minimum set of information that a voting system will report. They do not prohibit any voting system from reporting additional information that may be required by jurisdictions or otherwise found to be useful.

1.1.10-E – Report all votes cast

All systems must be able to produce an accurate, human-readable report of all votes cast.

Discussion

Binary document formats and text containing markup tags are not considered human-readable. The system may generate such documents, but it must also provide the functionality to render those documents in human-readable form (for example, by including the necessary reader application).

1.1.10-F – Account for all cast ballots and all valid votes

All systems must produce vote data reports that account for all cast ballots and all valid votes.

1.1.10-G Discrepancies detectable

Any discrepancy that is detectable by the system must be flagged in the system by an annotation or error message in the affected report or a separate discrepancy report.

Discussion

If this requirement is applicable, then the system has failed to satisfy Requirement 1.1.10-G and is therefore non-conforming. Nevertheless, in practice it is essential that discrepancies be flagged by the system as much as possible so that they are not overlooked by election judges. The system cannot detect discrepancies if no single voting device is ever in possession of a sufficient set of data.

1.1.10-H – Reporting combined precincts

The voting system must be capable of generating reports that consolidate vote data from selected precincts.

Discussion

Jurisdictions in which more than one precinct may vote at the same location on either the same ballot style or a different ballot style may desire reports that consolidate the voting location.

1.1.10-I – Precinct reporting devices, no tallies before polls close

The voting system must prevent the printing of vote data reports and extracting vote tally data before the polls close.

Discussion

Providing ballot counts does not violate this requirement. The prohibition is against providing vote totals. Ballot counts are required for ballot accounting, but early extraction of vote totals is an enabler of election fraud.

1.1.10-J – Report categories of cast ballots

All voting systems must report the number of ballots both in total and broken down by ballot style and by selected units of political geography including county, city, town or township, ward, precinct, and precinct split, for the following categories of cast ballots:

1. All read ballots and all counted ballots
2. For multi-page ballots, the number of different pages read, and number counted
3. Recallable read ballots and counted ballots
4. UOCAVA read ballots and counted ballots
5. Absentee read and counted ballots
6. Blank ballots (ballots containing no votes)

Discussion

There is no sub-requirement for separate reporting of provisional cast ballots because the system is unlikely to know whether a ballot is provisional until it is successfully read. Some jurisdictions find the number of blank ballots to be useful. Blank ballots sometimes represent a protest vote.

1.1.10-K – Report read ballots by party

Systems must report separate totals for each party in primary elections when reporting categories of read and counted cast ballots.

1.1.10-L – Report counted ballots by contest

All systems must report the number of counted ballots for each relevant N-of-M or cumulative voting contest.

Discussion

The count by contest could be inferred from the other counts that are broken down by ballot configuration, but providing this figure explicitly will make it easier to account for every vote. N-of-M in this requirement includes the most common type of contest, 1-of-M.

1.1.10-M – Report votes for each contest option

All systems must report the vote totals for each contest option in each relevant N-of-M or cumulative voting contest.

Discussion

N-of-M in this requirement includes the most common type of contest, 1-of-M.

1.1.10-N – Report overvotes for each contest

Systems must report the number of overvotes for each relevant N-of-M or cumulative voting contest.

Discussion

This count refers to votes lost to overvoting, not of ballots containing overvotes. This means that a ballot that overvotes an N-of-M contest would contribute N to the count of overvotes for that contest.

1.1.10-O – Reporting overvotes, ad hoc queries

All systems must be capable of producing a consolidated report of the combination of overvotes for any contest that is selected by an authorized official (for example, the number of overvotes in a given contest combining candidate A and candidate B, or combining candidate A and candidate C).

1.1.10-P – Report undervotes for each contest

All systems must report the number of undervotes for each relevant N-of-M or cumulative voting contest.

Discussion

Counting ballots containing undervotes instead of votes lost to undervoting is insufficient.

1.1.10-Q – Ranked choice voting, report results

Systems implementing ranked choice voting must report the contest option vote totals for each ranked choice contest for each round of tabulation.

Discussion

This requirement is minimal. Since ranked choice voting is not currently in wide use, it is not clear what needs to be reported, how bogus orderings are reported, or how it would be done in multiple reporting contexts.

1.1.10-R – Include all categories of votes

Systems must report all following categories of votes in the consolidated reports:

1. In-person voting
2. Absentee voting
3. Write-ins

4. Accepted recallable ballots
5. Accepted reviewed ballots

1.1.10-S – Post-election reports in common data format

The voting system must include support for the NIST 1500-100 CDF specification for post-election reports.

External reference: NIST 1500-100 CDF

1.1.10-T – CVR export and import in common data format

The voting system must include support for the NIST 1500-102 CDF specification for cast vote records for exporting a collection of CVRs from the device that created the CVRs and for importing a collection of CVRs into devices that process CVRs.

Discussion

This requirement concerns export of CVRs from devices such as scanners or code and bar-code reading devices and import of the CVRs into adjudication devices, tabulators, and audit devices.

External reference: NIST 1500-102 CDF

1.1.10-U – Reports are time stamped

All reports must include the date and time of the report's generation, including hours, minutes, and seconds. Timestamps in reports need to comply with ISO 8601, provide all four digits of the year, and include the time zone.

External reference: ISO 8601

1.2 – The voting system is designed to function correctly under real-world operating conditions.

1.2-A – Assessment of accuracy

The voting system's accuracy must be assessed by using a combination of evidence items gathered during the entire course of testing, including:

1. A measurement of how accurately voter marks are recognized as valid or not valid according to manufacturer specifications.
2. A measurement of how accurately voter marks are tabulated and reported as results.
3. An assessment of whether the remaining VVSG requirements are satisfied.

Discussion

A voting system cannot be determined as accurate without some uncertainty; thus, a judgement must be made based on evidence. In this case, a volume test is used under real-world conditions, and evidence collected throughout the test campaign as to whether the voting system satisfies all other relevant VVSG requirements.

Prior VVSG source: New requirement

1.2-A.1 – Minimum ballot positions

A minimum of 10,000,000 ballot positions must be read by the voting system and tabulated accurately.

Discussion

The value of 10,000,000 ballot positions is taken from VVSG 1.0, however it is used here as the minimum number of ballot positions to test without error. If a larger number of ballot positions is used, there still can be no error.

Prior VVSG source: VVSG-1.0 - 4.1.1

1.2-A.2 – Ballot position distribution

The ballot positions must be spread across devices according to a typical volume per device in a typical election.

Discussion

The test lab determines the typical volume per device and then spreads the number of ballot positions to be tested accordingly across the devices, for example, 10% to the ballot marking device (BMD), 40% to the voter facing scanner, etc.

Prior VVSG source: New requirement

1.2-A.3 – Mark quality

For devices that read and interpret human-made marks on ballots, the mark quality of the marks must be spread across the manufacturer's published specifications for valid marks and invalid marks according to expected distributions in typical elections.

Discussion

The goal of this requirement is to model real-world conditions. The test lab would prepare, using the manufacturer's specifications for valid marks, a set of test ballots in which mark quality will vary as it would in typical elections. In the case of marks that are borderline valid or invalid, a scanner may flag the marks as requiring adjudication.

Prior VVSG source: New requirement

1.2-B – Assessment of reliability

The voting system's reliability must be assessed using a combination of evidence items gathered during the entire course of testing, including:

1. Continuous operation of the voting system under typical environmental conditions.
2. Continuous operation of the voting system under varied environmental conditions across defined ranges.
3. An assessment of the manufacturer's statement of the reliability of the voting system by applying best practices for reliability engineering practices and standard reliability analysis methods (e.g., failure modes and effects analysis (FMEA)).

Discussion

As with accuracy, reliability cannot be positively ascertained; a judgment of reliability has to be determined from evidence. In this case, a volume test is used to determine the reliability of the voting system operations, as well as data from the test campaign regarding relevant VVSG requirements. In bullet 3, a manufacturer needs to show that reliability has been built into the voting system using a reliability analysis such as in FMEA. Consequently, the test lab has to assess the manufacturer's statement of reliability and weigh the performance of the voting system against that assessment.

Prior VVSG source: VVSG-1.0 – 4.3.5
VVSG-1.1 – 4.1.1

1.2-B.1 – Continuous operation – typical environmental conditions

The voting system must operate for a continuous period of at least 163 hours during which ballots are cast and ballot positions are read and tabulated without error. Table 1 shows the volume of ballots that must be cast during this period for vote-capture devices. The duration of the testing is as follows:

1. When testing a single device, e.g., a single BMD, the period of testing must be no less than 163 hours.
2. When testing two or more of the same device, e.g., two identical BMDs, the period of testing must be no less than 81 hours.

Discussion

This requirement is, in essence, a volume test in which the voting system is expected to operate continuously for 7 days without error. A form of this requirement is in VVSG 1.0; VVSG 1.1 omitted it entirely. The continuous operation may occur under typical expected temperatures and humidity such as may be found in a standard test lab environment. For hybrid devices such as a BMD combined with a tabulator, two devices should be tested for the 163-hour duration, e.g., one tested as a tabulator, one tested as a BMD. For mixed mode devices such as an accessible BMD used for all voters, the modes should be alternated during the testing.

Prior VVSG source: VVSG-1.0 - 4.1.2-A.2

DEVICE	VOLUME/HOUR
CENTRAL SCANNER	Manufacturer's stated maximum volume/4
VOTER FACING SCANNER	100
BMD INCLUDING ACCESSIBLE VERSION	Ballots cast for at least 15 minutes per hour

Table 1 – Volume per hour for vote-capture devices

1.2-B.2 – Continuous operation – varied environmental conditions

The voting system must operate for a continuous period of at least 24 hours during which ballots are cast and ballot positions are read and tabulated without error and in which temperature and humidity are varied.

1. The temperature must range from 41 °F to 104 °F (5 °C to 40 °C).
2. The relative humidity must range from 5 % to 85 %, noncondensing.

Discussion

In VVSG 1.0, the tests for humidity and temperature are included as requirements. For the VVSG 2.0, the same material will be specified as part of an EAC-governed test assertion and not included here.

Prior VVSG source: VVSG-1.0 - 4.1.2

1.2-B.3 – Failure Modes and Effect Analysis (FEMA)

The manufacturer must ensure the reliability of the voting system by applying best practices for reliability engineering practices and standard reliability analysis methods, for example, failure modes and effects analysis (FMEA).

Discussion

Manufacturers are now required to apply best practices to assure reliability in addition to the volume test-related requirements. If using FMEA for the manufacturer's reliability analysis, each specific, individual, identified failure mode would be assigned a probability, and the system probability of failure would then be derived mathematically. Since the underlying probabilities are likely to depend on the volume that a device is expected to handle in the course of the election, minimum values for the assumed volume per device per election. Other credible forms of reliability analysis could be used, provided they are widely used and accepted in the reliability measurement field.

Prior VVSG source: VVSG-1.1-Vol2 – 5.6.6.2

1.2-C – No single point of failure

All systems must protect against a single point of failure that would prevent further voting at the polling place.

Prior VVSG source: VVSG 2007 - 6.3.1-B

1.2-D – Protect against failure of input and storage devices

All systems must withstand, without loss of data, the failure of any data input or storage device.

Prior VVSG source: VVSG 2007 - 6.3.1-C

1.2-E – Reliably detectable marks

For an optical scanner, the system must detect marks for detectable and marginal marks consistent with system mark specifications.

Discussion

The specification may have parameters for different configuration values. It should also state the degree of uncertainty.

Prior VVSG source: VVSG 2007 - 4.1.2-A.2

1.2-F – Misfeed rate benchmark

The misfeed rate must not exceed 0.002 (1 / 500).

Discussion

Multiple feeds, misfeeds (jams), and rejections of ballots that meet all manufacturer specifications are all treated collectively as "misfeeds" for benchmarking purposes; that is, only a single count is maintained.

Prior VVSG source: VVSG 2007 - 6.33

1.2-G – Respond gracefully to stress of system limits

The system must be able to respond gracefully to attempts to process more than the expected number of ballots per precinct, more than the expected number of precincts, higher than expected volume or ballot tabulation rate, or any similar conditions that tend to overload the system's capacity to process, store, and report data.

Discussion

In particular, this requirement should be verified through operational testing if the limit is practically testable.

Prior VVSG source: VVSG 2007 - 5.2.3-C

1.2-H – Handle realistic volume

The system must be able to handle a realistic volume of activities in conditions approximating normal use in an entire election process, from election definition through reporting and auditing final results.

Discussion

Data collected during this test contribute substantially to the evaluations of reliability, accuracy, and misfeed rate.

Prior VVSG source: VVSG 2007 - 5.2.3-D

1.3 – Voting system design supports evaluation methods enabling testers to clearly distinguish systems that correctly implement specified properties from those that do not.

1.3-A – Identifiability of basic and compound system components

The provided documentation and equipment must ensure that a tester is able to clearly and unambiguously identify the full set of the basic (not made of any components) and compound (made up of other components) elements of the system.

Discussion

This is a basic condition necessary for a tester to be able to properly distinguish whether or not a system has correctly implemented specified properties or not.

It may be fulfilled by satisfying the documentation-specific guidelines of principle 3, and by providing information in the Technical Data Package (TDP) that will support this kind of understanding.

Prior VVSG source: New Requirement

1.3-B – Comprehensible processes that form system configurations

The provided documentation and equipment must ensure that a tester is able to clearly understand how particular configurations of process and technology are formed by combining their basic (and component) elements to produce the whole, final working system (whether in software, hardware, telecom, process, data, or other implemented aspect).

Discussion

This is a basic condition necessary for a tester to be able to properly distinguish whether or not a system has correctly implemented specified properties or not.

It may be fulfilled by satisfying the documentation-specific guidelines of principle 3, and by providing information in the Technical Data Package (TDP) that will support this kind of understanding.

Prior VVSG source: New Requirement

1.3-C – Observable configurations via plausible observation methods

The provided documentation and equipment must ensure that a tester is able to identify and select plausible observational tools, techniques, or strategies that can be used to observe signs of the system configurations.

Discussion

This is a basic condition necessary for a tester to be able to properly distinguish whether or not a system has correctly implemented specified properties or not.

It may be fulfilled by satisfying the documentation-specific guidelines of principle 3, and by providing information in the Technical Data Package (TDP) that will support this kind of understanding.

Prior VVSG source: New Requirement

1.3-D – Identifiable resolution limits for observation methods

From the provided documentation and equipment, for the observational tools, techniques, or strategies, a tester must be able to determine how well they can actually detect and distinguish each type of element and interconnection of elements in a system configuration.

Discussion

Every observational or measurement method has a limit to their resolution. Resolution is the threshold beyond which one cannot determine any more differences between two different things. This concept is sometimes known as the *just noticeable difference* of an observational method. This is like moving two things so close together that a given observer, eventually, cannot see powerfully enough to distinguish distances (differences) too small to detect with that technique. By identifying these limits, each evaluation method explicitly defines its power to distinguish certain observable configurations and characteristics from others.

This is a basic condition necessary for a tester to properly distinguish whether or not a system has correctly implemented specified properties or not.

It may be fulfilled by satisfying the documentation-specific guidelines of principle 3, and by providing information in the TDP that will support this kind of understanding.

Prior VVSG source: New Requirement

1.3-E – Description of observational noise and consequences for observational methods

From the provided documentation and equipment, for the observational tools, techniques, or strategies, a tester must be able to:

- determine what sources of noise will likely arise from observing a given system configuration completely by some observational method;
- map observable signs of system configurations (through that noise) to actual attributes of system configurations.

Discussion

It is often the case, when observing a system during testing, that one cannot always *directly* see what they are attempting to observe. Instead, one often sees *indirectly* observable signs of facts that would most likely be true if one could observe the system or component directly. Thus, much of the task of testing is to be sure that one can strongly relate the secondary facts of directly observable signs to those aspects of a system that may not be directly observable at all. In this way, a tester always acknowledges the degree to which they can directly access signs of what they are actually evaluating.

In addition, very often the methods used for observing those signs may introduce some noise or error into the process for observing configurations. As a result, if not accounted for, such factors can significantly affect the degree to which one can understand and rely upon the relationship of the observed results to the configuration they strive to observe.

This is a basic condition necessary for a tester to properly distinguish whether or not a system has correctly implemented specified properties or not.

It may be fulfilled by satisfying the documentation-specific guidelines of principle 3, and by providing information in the TDP that will support this kind of understanding.

Prior VVSG source: New Requirement

1.3-F – Explicitly-stated performance criteria

The provided documentation and equipment must ensure that a tester is able to state or use criteria that enable them to unambiguously decide whether or not an observed configuration exhibits intended properties.

Discussion

Before one can begin to evaluate the performance of a given system task (that is, a given system-implemented election function or process), one must be able to formulate some statements of facts that must be true of the original system configuration when there are observable signs of system configurations and their behaviors.

This is a basic condition necessary for a tester to properly distinguish whether or not a system has correctly implemented specified properties or not.

It may be fulfilled by satisfying the documentation-specific guidelines of principle 3, and by providing information in the TDP that will support this kind of understanding.

Prior VVSG source: New Requirement

1.3-G – Creation and execution of evaluation methods

The provided documentation and equipment must ensure that a tester is able to derive, construct, and execute plausible evaluation methods (test methods, etc.) that can demonstrate an ability to:

1. observe valid and invalid system configurations through plausible use of observational tools or techniques;
2. decide whether or not a given system configuration has satisfied the stated performance criteria;
3. report the findings resulting from their ability to distinguish correct from incorrect configurations of the system.

Discussion

This is a basic condition that is both *necessary and sufficient* for a tester to properly distinguish whether or not a system has correctly implemented specified properties or not. It includes and relies upon the satisfaction of the other testability requirements (1.3-A – 1.3-F).

It may be fulfilled by satisfying the documentation-specific guidelines of principle 3, and by providing information in the TDP that will support this kind of understanding.

Prior VVSG source: New Requirement

Principle 2
High Quality Implementation

The voting system is implemented using high quality best practices.

2.1 - The voting system and its software are implemented using trustworthy materials and best practices in software development.

2.2 - The voting system is implemented using best practice user-centered design methods that consider a wide range of representative voters, including those with and without disabilities, and election workers.

2.3 - Voting system logic is clear, meaningful, and well-structured.

2.4 - Voting system structure is modular, scalable, and robust.

2.5 – The voting system supports system processes and data with integrity.

2.6 - The voting system handles errors robustly and gracefully recovers from failure.

2.7 - The voting system performs reliably in anticipated physical environments.

Principle 2
High Quality Implementation

This principle covers core processes and functions that contribute to a voting system that has been implemented for quality. The requirements in this principle are basic best practices -- not a complete set of all quality practices. The Guidelines under Principle 2 are:

1 - **Software quality**, including acceptable programming languages and coding styles, as well as coding constructs that should or should not be used to improve software integrity and security. Additional requirements deal with handling errors or device failures, and others cover electrical components.

2 - **Design and implementation process** so that the voting system can be used effectively by voters and election staff.

3 - Voting system logic or the overall structuring of voting system software. The goal is that the software structure be easily understood and clear to audiences such as test labs and maintained without causing major changes in the software structure.

4 - **Modularity** and complexity of the system software structure.

5 - System processes and data using basic best practices for software integrity and secure coding constructs. The Election Assistance Commission (EAC), working with voting system test labs, may augment or change these requirements based on the discovery of new vulnerabilities or emerging new threats.

5 and 6 - **Graceful recovery** the capability of the voting system to handle and recover from errors, including failures of devices and components.

7 - **Physical environments** includes the ability of a voting device to withstand influences from its physical environment whether due to humidity, temperature, shock, vibration, electrical, or related influences.

The requirements on electrical disturbances are primarily covered by conformance to the Federal Communications Commission's regulation, Part 15, Class B [FCC19a]. The requirements here address items not covered by Class B, including the behavior of specific voting devices in the presence of electrical disturbances and cases where voting devices might interact with other devices or people.

2.1 - The voting system and its software are implemented using trustworthy materials and best practices in software development.

2.1-A – Acceptable programming languages

Application logic must be produced in a high-level programming language that has all of the following control constructs:

1. Sequence
2. Loop with exit condition (for example, for, while, or do-loops)
3. If/Then/Else conditional
4. Case conditional
5. Block-structured exception handling (for example, try/throw/catch).

This requirement can be satisfied by using COTS extension packages to add missing control constructs to languages that could not otherwise conform.

Discussion

A list of acceptable programming languages may be specified by the EAC in conjunction with voting system test labs.

By excluding border logic, this requirement allows the use of assembly language for hardware-related segments, such as device controllers and handler programs. It also allows the use of an externally-imposed language for interacting with an Application Program Interface (API) or database query engine. However, the special code should be insulated from the bulk of the code, for example, by wrapping it in callable units expressed in the prevailing language to minimize the number of places that special code appears.

The use of non-COTS extension packages or manufacturer-specific code for this purpose is not acceptable, as it would place an unreasonable burden on the test lab to verify the soundness of an unproven extension (effectively a new programming language). The package needs to have a proven track record of performance supporting the assertion that it would be stable and suitable for use in voting systems, just as the compiler or interpreter for the base programming language does.

Prior VVSG source: VVSG 2007 - 6.4.1.2-A
VVSG 2007 - 6.4.1.5-A.1

2.1-B – COTS language extensions are acceptable

Requirement 2.1-A may be satisfied by using COTS extension packages to add missing control constructs to languages that could not otherwise conform.

Discussion

The use of non-COTS extension packages or manufacturer-specific code for this purpose is not acceptable, as it would place an unreasonable burden on the test lab to verify the soundness of an unproven extension (effectively a new programming language). The package must have a proven track record of performance supporting the assertion that it would be stable and suitable for use in voting systems, just as the compiler or interpreter for the base programming language must.

Prior VVSG source: VVSG 2007 - 6.4.1.2-A.1

2.1-C – Acceptable coding conventions

Application logic must adhere to a published, credible set of coding rules, conventions, or standards (called "coding conventions") that enhance the workmanship, security, integrity, testability, and maintainability of applications.

Discussion

Coding conventions may be specified by the EAC in conjunction with voting system test labs.

Prior VVSG source: VVSG 2007 - 6.4.1.3-A

2.1-D – Records last at least 22 months

All systems must maintain the integrity of election management, voting, and audit data, including cast vote records (CVRs), during an election and for a period of at least 22 months afterward, in temperatures ranging from 5 C to 40 C (41 F to 104 F) and relative humidity from 5% to 85%, non-condensing.

Prior VVSG source: VVSG 2007 - 6.5.1-A

2.1.1 – Workmanship

2.1.1-A – General build quality

All manufacturers of voting systems must practice proper workmanship.

Prior VVSG source: VVSG 2007 - 6.4.3-A

2.1.1-B – High quality products

All manufacturers must adopt and adhere to practices and procedures that ensure their products are free from damage or defect that could make them unsatisfactory for their intended purpose.

Prior VVSG source: VVSG 2007 - 6.4.3-A.1

2.1.1-C – High quality parts

All manufacturers must ensure that components provided by external suppliers are free from damage or defect that could make them unsatisfactory or hazardous when used for their intended purpose.

Prior VVSG source: VVSG 2007 - 6.4.3-A.2

2.1.1-D – Suitability of COTS components

Manufacturers must ensure that all COTS components included in their voting systems are designed to be suitable for their intended use under the requirements specified by the VVSG 2.0.

Discussion

For example, if the operating or storage environmental conditions specified by the manufacturer of a printer do not meet or exceed these requirements, a system that includes that printer cannot be found conforming.

Prior VVSG source: VVSG 2007 - 6.4.3-B

2.1.1-E – Durability

Voting systems must be designed to withstand normal use without deterioration for a period of ten years.

Prior VVSG source: VVSG 2007 - 6.4.4-A

2.1.1-F – Durability of paper

Paper specified for use with the voting system must conform to the applicable specifications contained within the Government Paper Specification Standards, February 1999 No. 11, or the government standards that have superseded them.

Discussion

This is to ensure that paper records will be of adequate quality to survive the handling necessary for recounts, audits, etc. without problematic degradation. The Government Paper Specification

Standards include different specifications for different kinds of paper. As of 2007-04-05, the Government Paper Specification Standards, February 1999 No. 11, are available at http://www.gpo.gov/acquisition/paperspecs.htm [GPO19].

Prior VVSG source: VVSG 2007 - 6.4.4-B

2.1.2 – Maintainability

2.1.2-A – Electronic device maintainability

Electronic devices must exhibit the following physical attributes:

1. labels and the identification of test points,
2. built-in test and diagnostic circuitry or physical indicators of condition,
3. labels and alarms related to failures, and
4. features that allow non-technicians to perform routine maintenance tasks.

Prior VVSG source: VVSG 2007 - 6.4.5-A

2.1.2-B – System maintainability

Voting systems must allow for:

1. a non-technician to easily detect that the equipment has failed;
2. a trained technician to easily diagnose problems;
3. easy access to components for replacement;
4. easy adjustment, alignment, and tuning of components; and
5. low false alarm rates (that is, indications of problems that do not exist).

Prior VVSG source: VVSG 2007 - 6.4.5-B

2.1.2-C – Nameplate and labels

All voting devices must:

1. Display a permanently affixed nameplate or label containing the name of the manufacturer or manufacturer, the name of the device, its part or model number, its revision identifier, its serial number, and if applicable, its power requirements.

2. Display a separate data plate containing a schedule for and list of operations required to service or to perform preventive maintenance, or a reference to where this can be found in the Voting Equipment User Documentation.
3. Display advisory caution and warning instructions to ensure safe operation of the equipment and to avoid exposure to hazardous electrical voltages and moving parts at all locations where operation or exposure may occur.

Prior VVSG source: VVSG 2007 - 6.4.5-C

2.2 – The voting system is implemented using best practice user-centered design methods that consider a wide range of representative voters, including those with and without disabilities, and election workers.

2.2-A – User-centered design process

The manufacturer must submit a report providing documentation that the system was developed following best practices for a user-centered design process.

The report must include, at a minimum:

- A listing of user-centered design methods used
- The types of voters and election workers included in those methods
- How those methods were integrated into the overall implementation process
- How the results of those methods contributed to developing the final features and design of the voting system

Discussion

The goal of this requirement is to allow the manufacturer to demonstrate, through the report, the way their implementation process included user-centered design methods.

"ISO-9241-210:2010 Ergonomics of human-system interaction—Part 210: Human-centered design for interactive systems provides requirements and recommendations for human-centered principles and activities throughout the life-cycle of computer-based interactive systems." It includes the idea of iterative cycles of user research to understand the context of use and user needs, creating prototypes or versions, and testing to confirm that the product meets the identified requirements.

This requirement does not specify the exact user-centered design methods to be used, or their number or timing.

The ISO group of requirements, S*oftware engineering -- Software product Quality Requirements and Evaluation (SQuaRE) -- Common Industry Format (CIF)* includes several standards that are a useful framework for reporting on user-centered design activities and usability reports.

- • ISO/IEC TR 25060:2010: General framework for usability-related information
- • ISO/IEC 25063:2014: Context of use description
- • ISO/IEC 25062:2006: Usability test reports
- • ISO/IEC 25064:2013: User needs report
- • ISO/IEC 25066:2016 Evaluation report

The final research report from the Los Angeles *Voting Systems for All* People project is an example of a summary report of a user-centered design process to design a voting system.

External reference:	ISO 9241-210:2010 – Human-centered design for interactive systems
Related requirements	8.3-A-Usability testing with voters 8.4-A-Usability testing with election workers

2.3 - Voting system logic is clear, meaningful, and well-structured.

2.3-A – Block-structured exception handling

Application logic must handle exceptions using block-structured exception handling constructs.

Prior VVSG source: VVSG 2007 - 6.4.1.5-A

2.3-B – Legacy library units

If application logic makes use of any COTS or third-party logic callable units that do not throw exceptions when exceptional conditions occur, those callable units must be wrapped in callable units that check for the relevant error conditions and translate them into exceptions, and the remainder of application logic must use only the wrapped version.

Prior VVSG source: VVSG 2007 - 6.4.1.5-A.1

2.3-C – Separation of code and data

Application logic must not compile or interpret configuration data or other input data as a programming language.

Discussion

The applicable requirement in VVSG2005 reads "Operator intervention or logic that evaluates received or stored data must not re-direct program control within a program routine." That attempt to define what it means to compile or interpret data as a programming language caused confusion.

Distinguishing what is a programming language from what is not requires some professional judgment. However, in general, sequential execution of imperative instructions is a characteristic of conventional programming languages that should not be exhibited by configuration data. Configuration data must be declarative or informative in nature, not imperative.

For example: Configuration data can contain a template that informs a report generating application about the form and content of a report that it should generate. However, configuration data cannot contain instructions that are executed or interpreted to generate a report, essentially embedding the logic of the report generator inside the configuration data.

The reasons for this requirement are

- mingling code and data is bad design, and
- embedding logic within configuration data evades the conformity assessment process for application logic.

Prior VVSG source: VVSG 2007 - 6.4.1.5-C

2.3-D – Hard-coded passwords and keys

Voting system software must not contain hard-coded

1. passwords, or
2. cryptographic keys

Discussion

Many examples of this vulnerability have previously been identified in voting system software. Additional information about this vulnerability can be found at **CWE-259: Use of Hard-coded Password** and **CWE-321: Use of Hard-coded Cryptographic Key.**

External references: CWE-259: Use of Hard-coded Password
CWE-321: Use of Hard-coded Cryptographic Key

2.3.1 – Software flow

2.3.1-A – Unstructured control flow

Application logic must contain no unstructured control constructs.

Discussion

Although it is typically developed by the voting system manufacturer, border logic is constrained by the requirements of the third-party or COTS interface with which it interacts. It is not always possible for border logic to achieve its function while conforming to standard coding conventions. For this reason, border logic should be minimized relative to application logic and where possible, wrapped in a conforming interface. An example of border logic that could not be so wrapped is a customized boot manager that connects a bootable voting application to a COTS BIOS.

2.3.1-B – Goto

Arbitrary branches (also known as gotos) must not be used.

Prior VVSG source: VVSG 2007 - 6.4.1.5-B.1

2.3.1-C – Intentional exceptions

Exceptions must only be used for abnormal conditions. Exceptions must not be used to redirect the flow of control in normal ("non-exceptional") conditions.

Discussion

"Intentional exceptions" cannot be used as a substitute for arbitrary branch. Normal, expected events, such as reaching the end of a file that is being read from beginning to end or receiving invalid input from a user interface, are not exceptional conditions and should not be implemented using exception handlers.

Prior VVSG source: VVSG 2007 - 6.4.1.5-B.2

2.3.1-D – Unstructured exception handling

Unstructured exception handling (for example, On Error GoTo, setjmp/longjmp, or explicit tests for error conditions after every executable statement) is prohibited.

Discussion

The internal use of such constructs by a COTS extension package that adds block-structured exception handling to a programming language that otherwise would not have it, as described in Requirement 2.3-B, is allowed. Similarly, it is not a problem that source code written in a high-level programming language is compiled into low-level machine code that contains arbitrary branches. It is only the direct use of low-level constructs in application logic that presents a problem.

Prior VVSG source: VVSG 2007 - 6.4.1.5-B.3

2.4 - Voting system structure is modular, scalable, and robust.

2.4-A – Modularity

Application logic must be designed in a modular fashion.

Discussion

The modularity rules described here apply to the component submodules of a library.

Prior VVSG source: VVSG 2007 - 6.4.1.4-A

2.4-B – Module testability

Each module must have a specific function that can be tested and verified independently of the remainder of the code.

Discussion

In practice, some additional modules (such as library modules) can be needed to compile the module being tested, but the modular construction allows the supporting modules to be replaced by special test versions that support test objectives.

Prior VVSG source: VVSG 2007 - 6.4.1.4-A.1

2.4-C – Module size and identification

Modules must be small and easily identifiable.

Prior VVSG source: VVSG 2007 - 6.4.1.4-B

2.4-D – Lookup tables in separate files

Read-only lookup tables longer than 25 lines must be placed in separate files from other source code if the programming language permits it.

Prior VVSG source: VVSG 2007 - 6.4.1.4-B.2

2.5 - The voting system supports system processes and data with integrity.

2.5-A – Self-modifying code

Application logic must not be self-modifying.

Prior VVSG source: VVSG 2007 - 6.4.1.7-A.1

2.5-B – Unsafe concurrency

Application logic must be free of race conditions, deadlocks, livelocks, and resource starvation.

Prior VVSG source: VVSG 2007 - 6.4.1.7-A.2

2.5.1 – Code integrity

2.5.1-A – COTS compilers

If compiled code is used, it must only be compiled using a COTS compiler.

Discussion

This prohibits the use of arbitrary, nonstandard compilers and, consequently, the invention of new programming languages.

Prior VVSG source: VVSG 2007 - 6.4.1.7-A.3

2.5.1-B – Interpreted code, specific COTS interpreter

If interpreted code is used, it must only be run under a specific, identified version of a COTS runtime interpreter.

Discussion

This ensures that:

- no arbitrary, nonstandard interpreted languages are used, and
- the software tested and approved during the conformity assessment process does not change behavior because of a change to the interpreter.

Prior VVSG source: VVSG 2007 - 6.4.1.7-A.4

2.5.1-C – Prevent tampering with code

Programmed devices must prevent replacing or modifying executable or interpreted code (for example, by other programs on the system, by people physically replacing the memory or medium containing the code, or by faulty code) except where this access is necessary to conduct the voting process.

Discussion

This requirement can be partially satisfied through a combination of:

- read-only memory (ROM),
- the memory protection implemented by most popular COTS operating systems,
- error checking, and
- access and integrity controls.

Prior VVSG source: VVSG 2007 - 6.4.1.7-B

2.5.1-D – Prevent tampering with data

All voting devices must prevent access to or manipulation of configuration data, vote data, or audit records (for example, by physically tampering with the medium or mechanism containing the data, by other programs on the system, or by faulty code) except where this access is necessary to conduct the voting process.

Discussion

This requirement can be partially satisfied through a combination of:

- the memory protection implemented by most popular COTS operating systems,
- error checking, and
- access and integrity controls.

Systems using mechanical counters to store vote data need to protect the counters from tampering. If vote data are stored on paper, the paper needs to be protected from tampering. Modification of audit records after they are created is never necessary.

Prior VVSG source: VVSG 2007 - 6.4.1.7-C

2.5.2 – Input/output errors

2.5.2-A – Monitoring and defending for I/O errors

Programmed devices must provide the capability to monitor the transfer quality of I/O operations, reporting the number and types of errors that occur and how they were corrected.

Prior VVSG source: VVSG 2007 - 6.4.1.7-D

2.5.2-B – Validate and filter input

The voting system must validate all input against expected parameters, such as data presence, length, type, format, uniqueness, or inclusion in a set of whitelisted values.

Discussion

Input includes data from any input source: input devices (such as touchscreens, keyboards, keypads, optical/digital scanners, and assistive devices), networking port, data port, or file.

Prior VVSG source: VVSG 2007 - 6.4.1.8-A.1

2.5.2-C – Detect garbage input

Programmed devices must check information inputs for completeness and validity.

Discussion

This general requirement applies to all programmed devices, while the specific ones following are only enforceable for application logic.

Prior VVSG source: VVSG 2007 - 6.4.1.8-A

2.5.2-D – Defend against garbage input

Programmed devices must ensure that incomplete or invalid inputs do not lead to irreversible error.

Prior VVSG source: VVSG 2007 - 6.4.1.8-A.1

2.5.3 – Output protection

2.5.3-A – Escaping and encoding output

Software output must be properly encoded, escaped, and sanitized.

Discussion

The output of a software module can be manipulated or abused by attackers in unexpected ways to perform malicious actions. Ensuring that outputted data is of an expected type or format assists in preventing this abuse. Additional information about this software weakness can be viewed in **CWE 116: Improper Encoding or Escaping of Output**.

External sources: CWE 116: Improper Encoding or Escaping of Output

2.5.3-B – Sanitize output

The voting system must sanitize all output to remove or neutralize the effects of any escape characters, control signals, or scripts contained in the data which could adversely manipulate the output source.

Discussion

Output includes data to any output source: output devices (such as touchscreens, LCD screens, printers, and assistive devices), networking port, data port, or file. This applies to all parts of the voting system including the election management system (EMS).

2.5.3-C – Stored injection

The voting system must sanitize all output to files and databases to remove or neutralize the effects of any escape characters, control signals, or scripts contained in the data which could adversely manipulate the voting system if the stored data is read or imported at a later date or by another part of the voting system.

Discussion

A stored injection attack saves malicious data which is harmless when stored, but which is potent when read later in a different context or when converted to a different format. For example, a malicious script might be written to a file and do no harm to the voting machine, but later be evaluated and harmful when the file is transferred and read by the EMS. Input should also be filtered, but sanitizing stored output provides defense in depth.

2.5.4 – Error handling

2.5.4-A – Mandatory internal error checking

Application logic that is vulnerable to the following types of errors must check for these errors at run time and respond defensively when they occur:

1. Common memory management errors, such as out-of-bounds accesses of arrays, strings, and buffers used to manage data

2. Uncontrolled format strings
3. CPU-level exceptions such as address and bus errors, dividing by zero, and the like
4. Variables that are not appropriately handled when out of expected boundaries
5. Numeric and integer overflows
6. Validation of array indices
7. Known programming language specific vulnerabilities

Discussion

Logic verification will show that some error checks cannot logically be triggered, and some exception handlers cannot logically be invoked. These checks and exception handlers are not redundant – they provide defense-in-depth against faults that escape detection during logic verification.

Prior VVSG source: VVSG 2007 - 6.4.1.8-B

2.5.4-B – Array overflows

If the application logic uses arrays, vectors, or any analogous data structures, and the programming language does not provide automatic run-time range checking of the indices, the indices must be ranged-checked on every access.

Discussion

Range checking code should not be duplicated before each access. Clean implementation approaches include:

- consistently using dedicated accessors (such as functions, methods, operations, subroutines, and procedures) that range-check the indices;
- defining and consistently using a new data type or class that encapsulates the range-checking logic;
- declaring the array using a template that causes all accessors to be range-checked; or
- declaring the array index to be a data type whose enforced range is matched to the size of the array.

Range-enforced data types or classes can be provided by the programming environment or they can be defined in application logic. If acceptable values of the index do not form a contiguous range, a map structure can be more appropriate than a vector.

Prior VVSG source: VVSG 2007 - 6.4.1.8-B.1

2.5.4-C – Buffer overflows

If an overflow does not automatically result in an exception, the application logic must explicitly check for and prevent the overflow.

Prior VVSG sources: VVSG 2007 - 6.4.1.8-B.2

2.5.4-D – CPU traps

The application logic must implement such handlers as needed to detect and respond to CPU-level exceptions.

Discussion

For example, under Unix, a CPU-level exception would manifest as a signal, so a signal handler is needed. If the platform supports it, it is preferable to translate CPU-level exceptions into software-level exceptions so that all exceptions can be handled in a consistent fashion within the voting application. However, not all platforms support it.

Prior VVSG source: VVSG 2007 - 6.4.1.8-B.3

2.5.4-E – Garbage input parameters

All scalar or enumerated type parameters whose valid ranges as used in a callable unit (such as function, method, operation, subroutine, and procedure) do not cover the entire ranges of their declared data types must be range-checked on entry to the unit.

Discussion

This applies to parameters of numeric types, character types, temporal types, and any other types for which the concept of range is well-defined. In cases where the restricted range is frequently used or associated with a meaningful concept within the scope of the application, the best approach is to define a new class or data type that encapsulates the range restriction, eliminating the need for range checks on each use.

This requirement deals with user input that is expected to contain errors. User input errors are a normal occurrence; the errors discussed here are grounds for throwing exceptions.

Prior VVSG source: VVSG 2007 - 6.4.1.8-B.4

2.5.4-F – Numeric overflows

If the programming language does not provide automatic run-time detection of numeric overflow, all arithmetic operations that could potentially overflow the relevant data type must be checked for overflow.

Discussion

Encapsulate overflow checking as much as possible.

Prior VVSG source: VVSG 2007 - 6.4.1.8-B.5

2.5.4-G – Uncontrolled format strings

Voting system software must not contain uncontrolled format strings.

Discussion

Many examples of this vulnerability have previously been identified in voting system software. Additional information about this vulnerability can be found at **CWE 134: Use of Externally-Controlled Format String**.

External reference: CWE 134: Use of Externally-Controlled Format String

2.5.4-H – Recommended internal error checking

Application logic that is vulnerable to the following types of errors must check for these errors at run time and respond defensively when they occur:

1. Pointer variable errors
2. Dynamic memory allocation and management errors

Prior VVSG source: VVSG 2007 - 6.4.1.8-C

2.5.4-I – Pointers

If application logic uses pointers or a similar mechanism for specifying absolute memory locations, the application logic must validate these pointers or addresses before they are used.

Discussion

The goal is to prevent improper overwriting, even if read-only memory would prevent the overwrite from succeeding. An attempted overwrite indicates a logic fault that must be corrected.

Pointer use that is fully encapsulated within a standard platform library is treated as COTS software.

Prior VVSG source: VVSG 2007 - 6.4.1.8-C.1

2.5.4-J – Memory mismanagement

If dynamic memory allocation is performed in application logic, the application logic must be able to be instrumented or analyzed with a COTS tool for detecting memory management errors.

Discussion

Dynamic memory allocation that is fully encapsulated within a standard platform library is treated as COTS software.

Prior VVSG source: VVSG 2007 - 6.4.1.8-D

2.5.4-K – Nullify freed pointers

If pointers are used, any pointer variables that remain within scope after the memory they point to is deallocated must be set to null or marked as invalid (pursuant to the idiom of the programming language used).

Discussion

If this is not done automatically by the programming environment, a callable unit should be dedicated to the task of deallocating memory and nullifying pointers. Equivalently, "smart pointers" like the C++ std::auto_ptr can be used to avoid the problem. One should not add assignments after every deallocation in the source code.

In languages using garbage collection, memory is not deallocated until all pointers to it have gone out of scope, so this requirement is moot.

Prior VVSG source: VVSG 2007 - 6.4.1.8-E

2.5.4-L – React to errors detected

Detecting any of the errors enumerated in these requirements must be treated as a complete failure of the callable unit in which the error was detected.

1. An appropriate exception must be thrown, and
2. Control must pass out of the unit immediately.

Prior VVSG source: VVSG 2007 - 6.4.1.8-F

2.5.4-M – Election integrity monitoring

To the extent possible, electronic devices must proactively detect or prevent basic violations of election integrity (for example, stuffing the ballot box or accumulating negative votes) and alert an election official or administrator if they occur.

Discussion

Equipment can only verify those conditions that are within the scope of what the equipment does. However, if the equipment can detect something that is blatantly wrong, it should do so and raise the alarm. This provides defense-in-depth to supplement procedural controls and auditing practices.

Prior VVSG source: VVSG 2007 - 6.4.1.8-K

2.5.4-N – SQL injection

The voting system application must defend against SQL injection.

Discussion

SQL injection is a classic type of software weakness still prevalent today. SQL injection is not just a web-based issue, as any application accepting untrusted user input and passing it to a database can be vulnerable. Additional information about this software weakness can be viewed in within **CWE 89: Improper Neutralization of Special Elements used in an SQL Command ('SQL Injection').**

External source: CWR 89: Improper Neutralization of Special Elements used in an SQL Command ('SQL Injection')

2.5.4-O – Parameterized queries

Any structured statement or command being prepared using dynamic data (including user input) to be sent to a database or other process must parameterize the data inputs and apply strict type casting and content filters on the data (such as prepared statements).

Discussion

Parametrized queries are a common defense against this class of software weakness.

2.6 - The voting system handles errors robustly and gracefully recovers from failure.

2.6-A – Surviving device failure

All systems must be capable of resuming normal operation following the correction of a failure in any device.

Prior VVSG source: VVSG 2007 - 6.4.1.9-A

2.6-B – No compromising voting or audit data

Exceptions and system recovery must be handled in a manner that protects the integrity of all recorded votes and audit log information.

Prior VVSG source: VVSG 2007 - 6.4.1.9-A

2.6-C – Surviving component failure

All voting devices must be capable of resuming normal operation following the correction of a failure in any component (for example, memory, CPU, ballot reader, or printer) provided that catastrophic electrical or mechanical damage has not occurred.

Prior VVSG source: VVSG 2007 - 6.4.1.9-C

2.6-D – Controlled recovery

Error conditions must be corrected in a controlled fashion so that system status can be restored to the initial state existing before the error occurred.

Discussion

"Initial state" refers to the state existing at the start of a logical transaction or operation. Transaction boundaries must be defined in a conscientious fashion to minimize the damage. The final state is optional because election officials responding to the error condition might want the opportunity to select a different state, such as a controlled shutdown with memory dump for later analysis.

Prior VVSG source: VVSG 2007 - 6.4.1.9-D

2.6-E – Nested error conditions

Nested error conditions that are corrected without reset, restart, reboot, or shutdown of the voting device must be corrected in a controlled sequence so that system status can be restored to the initial state existing before the first error occurred.

Prior VVSG source: VVSG 2007 - 6.4.1.9-D.1

2.6-F – Reset CPU error states

CPU-level exceptions that are corrected without reset, restart, reboot, or shutdown of the voting device must be handled in a manner that restores the CPU to a normal state and allows the system to log the event and recover as with a software-level exception.

Discussion

System developers should test to see how CPU-level exceptions are handled and make any changes necessary to ensure robust recovery. Invocation of any other error routine while the CPU is in an exception handling state is to be avoided – software error handlers often do not operate as intended when the CPU is in an exception handling state.

If the platform supports it, it is preferable to translate CPU-level exceptions into software-level exceptions so that all exceptions can be handled in a consistent fashion within the voting application. However, not all platforms support it.

Prior VVSG source: VVSG 2007 - 6.4.1.9-D.2

2.6-G – Coherent checkpoints

When recovering from non-catastrophic failure of a device or from any error or malfunction that is within the operator's ability to correct, the system must restore the device to the operating condition existing immediately before the error or failure, without loss or corruption of voting data previously stored in the device.

Discussion

If the system is left in something other than the last known good state for diagnostic reasons, this requirement clarifies that it must revert to the last known good state before being placed back into service.

Prior VVSG source: VVSG 2007 - 6.4.1.9-E

2.7 - The voting system performs reliably in anticipated physical environments.

2.7-A – Ability to support maintenance and repair physical environment conditions – non-operating

All voting systems must be able to withstand non-operating physical environmental conditions exercised in accordance with MIL-STD-810H, Method 516.6. Procedure VI [MIL19].

Discussion

This test simulates stresses faced during maintenance and repair.

External reference	MIL-STD-810H
Prior VVSG source:	VVSG-2007 - 5.1.4-A.1

2.7-B – Ability to support transport and storage physical environment conditions – non-operating

All voting systems must be able to withstand non-operating physical environmental conditions exercised in accordance with MIL-STD-810H, Method 514.6, Category 4—Truck/trailer - secured cargo, 2.1.3.1 Truck transportation over U. S. highways [MIL19].

Discussion

This test simulates stresses faced during transport between storage locations and polling places.

External reference	MIL-STD-810H
Prior VVSG source:	VVSG-2007 - 5.1.4-A.2

2.7-C – Ability to support storage temperatures in physical environment – non-operating

All voting systems must be able to withstand non-operating physical environmental conditions exercised in accordance with MIL-STD-810H: Method 502.5, Procedure I – Storage, and Method 501.5, Procedure I – Storage. The minimum temperature ***shall*** be -20 degrees C (-4 degrees F), and the maximum temperature ***shall*** be 60 degrees C (140 degrees F) [MIL19].

Discussion

This test simulates stresses faced during storage.

External reference	MIL-STD-810H
Prior VVSG source:	VVSG-2007 - 5.1.4-A.3

2.7-D – Ability to support storage humidity levels in physical environment – non-operating

All voting systems must be able to withstand non-operating physical environmental conditions exercised in accordance with humidity testing specified by MIL-STD-810H: Method 507.5, Natural Hot-humid (Cycle B3), with test conditions that simulate a storage environment. [MIL19].

Discussion

This test is intended to evaluate the ability of voting equipment to survive exposure to an uncontrolled temperature and humidity environment during storage.

External reference	MIL-STD-810H
Prior VVSG source:	VVSG-2007 - 5.1.4-A.4

2.7-E – Ability to operate as intended at low and high temperatures - operating

All voting systems must be able to withstand operating physical environmental conditions exercised in the low temperature and high temperature testing specified by MIL-STD-810H: Method 502.5, Procedure II–Operation and Method 501.5, Procedure II–Operation, with test conditions that simulate system operation [MIL19].

External reference	MIL-STD-810H
Prior VVSG source:	VVSG-2007 - 5.1.5-A.1

2.7-F – Ability to operate as intended at specified humidity conditions - operating

All voting systems must be able to withstand operating physical environmental conditions exercised in the humidity testing specified by MIL-STD-810-H: Method 507.5 with test conditions that simulate system operation [MIL19].

Prior VVSG source:	VVSG-2007 - 5.1.5-A.2

2.7.1 – Ability to withstand electrical disturbances

2.7.1-A – Electrical disturbances

All voting devices must continue to operate in the presence of electrical disturbances generated by other devices and people and must not cause electrical disruption to other devices and people.

Discussion

Voting devices located in a polling place or other places need to continue to operate despite disruption from electrical emanations generated by other devices, including static discharges from people. Likewise, voting devices need to operate without causing disruption to other devices and people due to electrical emanations from the devices.

2.7.1-B – FCC Part 15 Class A and B conformance

Voting devices must comply with the requirements of the Federal Communications Commission, Part 15:

1. Voting devices located in polling places must comply with Class B requirements.
2. Voting devices located in non-place setting, such as back offices, must minimally comply with Class A requirements.

2.7.1-C – Power supply from energy service provider

Voting devices located in polling places must be powered by a 120 V, single phase power supply derived from typical energy service providers.

Discussion

It is assumed that the AC power necessary to operate the voting system will be derived from the existing power distribution system of the facility housing the polling place. This single-phase power may be a leg of a 120/240 V single phase system, or a leg of a 120/208 V three-phase system, at a frequency of 60 Hz.

2.7.1-D – Power port connection to the facility power supply

All electronic voting systems installed in a polling place must comply with Class B emission limits affecting the power supply connection to the energy service provider.

Discussion

The normal operation of an electronic system can produce disturbances that will travel upstream and affect the power supply system of the polling place, creating a potential deviation from the expected

electromagnetic compatibility of the system. The issue is whether these actual disturbances (after possible mitigation means incorporated in the equipment) reach a significant level to exceed stipulated limits.

2.7.1-E – Leakage from grounding port

All electronic voting systems installed in a polling place must comply with limits of leakage currents effectively established by the trip threshold of all listed Ground Fault Current Interrupters (GFCI), if any, installed in the branch circuit supplying the voting system.

Discussion

Excessive leakage current is objectionable for two reasons:

- For a branch circuit or wall receptacle that could be provided with a GFCI (depending upon the wiring practice applied at the particular polling place), leakage current above the GFCI built-in trip point would cause the GFCI to trip and therefore disable the operation of the system.
- Should the power cord lose the connection to the equipment grounding conductor of the receptacle, a personnel hazard would occur. (Note the prohibition of "cheater" adapters in the discussion of general requirements for the polling place.)

2.7.1-F – Outages, sags, and swells

All electronic voting systems must be able to withstand, without disruption of normal operation or loss of data, a complete loss of power lasting two hours.

Discussion

The Information Technology industry has adopted a recommendation that IT equipment should be capable of operating correctly for swells reaching 120 % of the nominal system voltage with duration ranging from 3 ms to 0.5 s and permanent overvoltages up to 110 % of nominal system voltage.

2.7.1-G – Withstand conducted electrical disturbances

All electronic voting systems must withstand conducted electrical disturbances that affect the power ports of the system.

2.7.1-H – Emissions from other connected equipment

All elements of an electronic voting system must be able to withstand the conducted emissions generated by other elements of the voting system.

2.7.1-I – Electrostatic discharge immunity

All electronic voting systems must withstand, without disruption of normal operation or loss of data, electrostatic discharges (ESD) associated with human contact and contact with mobile equipment (such as service carts and wheelchairs).

Discussion

ESD events can originate from direct contact between an "intruder" (person or object) charged at a potential different from that of the units of the voting system, or from an approaching person about to touch the equipment – an "air discharge." The resulting discharge current can induce disturbances in the circuits of the equipment. This requirement is meant to ensure that voting devices are conformant to the typical ESD specifications met by other electronic devices used by the public such as ATMs and vending kiosks.

2.7.1-J – Radiated radio frequency emissions

All electronic voting systems installed in a polling place must comply with emission limits according to the Rules and Regulations of Class B for radiated radio-frequency emissions.

Discussion

Electronic equipment in general and modern high-speed digital electronic circuits in particular have the potential to produce unintentional radiated and conducted radio-frequency emissions over wide frequency ranges. These unintentional signals can interfere with the normal operation of other equipment, especially radio receivers, in close proximity.

Principle 3
Transparent

The voting system and voting processes are designed to provide transparency.

3.1 - The documentation describing the voting system design, operation, accessibility features, security measures, and other aspects of the voting system can be read and understood.

3.2 - The processes and transactions, both physical and digital, associated with the voting system are readily available for inspection.

3.3 - The public can understand and verify the operations of the voting system throughout the entirety of the election.

Principle 3
TRANSPARENT

The voting system and voting processes are designed to provide transparency.

Guideline 3.1 contains requirements for the documentation that manufacturers supply to jurisdictions that use their systems. In this context, "user" refers to election officials, and "system" refers to a voting system or individual voting device. The user documentation is also included in the technical date package (TDP) given to test labs. The sections in 3.1 cover

1 - System overview covers documentation that explains the physical and logical structure of the system, its components, how it is structured, details about the software, and so forth.

2 - System performance documentation gives details on how the system performs in normal operation as well as its constraints and limits.

3 - System security documentation describes the features of the system that provide or contribute to its security and includes how to operate the system securely. Physical security and audit are included in this documentation.

4 - Software installation documentation describes in exact detail what software is installed, how it is installed, and how it is to be maintained.

5 - System operations documentation deals with operating and using the equipment to conduct elections, including setup, testing, voting operations, reporting, and so forth.

6 - System maintenance documentation deals with proper maintenance of the voting equipment and how to correct various issues or problems.

7 - Training material lists what the manufacturer needs to cover about the personnel resources and training required for a jurisdiction to operate and maintain the system.

8 - Training documentation lays out various information that would be important when training users on the voting equipment.

It is not the intent of these requirements to prescribe an outline for user documentation. Manufacturers are encouraged to innovate in the quality and clarity of their user documentation.

In 3.2, Setup inspection documentation explains how to verify that the system is properly setup and configured, and how to monitor its operations.

In 3.3, Public documentation requirements cover details of how a manufacturer codes the election event log, implements a CDF, builds barcodes, and implements audits.

3.1 – The documentation describing the voting system design, operation, accessibility features, security measures, and other aspects of the voting system can be read and understood.

3.1.1 – System overview

3.1.1-A – System overview documentation

In the system overview, the manufacturer must provide information that enables the user to identify the functional and physical components of the system, how the components are structured, and the interfaces between them.

3.1.1-B – System overview, functional diagram

The system overview must include a high-level functional diagram of the voting system that includes all of its components. The diagram must portray how the various components relate and interact.

3.1.1-C – System description

The system description must include written descriptions, drawings, and diagrams that present, as applicable:

1. a description of the functional components (or subsystems) as defined by the manufacturer (for example, environment, election management and control, vote recording, vote conversion, reporting, and their logical relationships)
2. a description of the operational environment of the system that provides an overview of the hardware, firmware, software, and communications structure
3. a concept of operations that explains each system function and how the function is achieved in the design
4. descriptions of the functional and physical interfaces between components
5. identification of all COTS products (both hardware and software) included in the system or used as part of the system's operation, identifying the name, manufacturer, and version used for each such component
6. communications (dial-up, network) software
7. interfaces among internal components and interfaces with external systems

8. for components that interface with other components for which multiple products may be used, file specifications, data objects, or other means used for information exchange including the public standard used for such file specifications, data objects, or other means
9. benchmark directory listings for all software, firmware, and associated documentation included in the manufacturer's release in the order in which each piece of software or firmware would normally be installed upon system setup and installation

3.1.1-D – Identify software and firmware by origin

The system overview must include the identification of all software and firmware items, indicating items that were:

1. written in-house
2. written by a subcontractor
3. procured as COTS
4. procured and modified, including descriptions of the modifications to the software or firmware and to the default configuration options

3.1.1-E – Traceability of procured software

The system description must include a declaration that procured software items were obtained directly from the manufacturer or a licensed dealer or distributor.

Discussion

For most noncommercial software, this would mean a declaration that the software was downloaded from the canonical site or a trustworthy mirror. It is generally accepted practice for the core contributors to major open-source software packages to digitally sign the distributions. Verifying these signatures provides greater assurance that the package has not been modified.

3.1.2 – System performance

3.1.2-A – System performance

The manufacturer must provide system performance information including:

1. device capacities and limits that were stated in the implementation statement
2. if not already covered in the implementation statement, performance characteristics of each operating mode and function in terms of expected and maximum speed, throughput capacity, maximum volume (maximum number of voting positions and maximum number of ballot styles supported), and processing frequency
3. quality attributes such as reliability, maintainability, availability, usability, and portability
4. provisions for safety, security, privacy, and continuity of operation
5. design constraints, applicable standards, and compatibility requirements

3.1.2-B – Maximum tabulation rate

The maximum tabulation rate for a bulk-fed scanner must be documented by the manufacturer. This documentation must include the maximum tabulation rate for individual components that impact the overall maximum tabulation rate.

Discussion

The capacity to convert the marks on individual ballots into signals is uniquely important to central count systems.

3.1.2-C – Reliably detectable marks

For an optical scanner, the manufacturer must document what constitutes a reliably detectable mark versus a marginal mark.

3.1.2-D – Processing capabilities

The manufacturer must provide a listing of the system's functional processing capabilities, encompassing capabilities required by the VVSG, and any additional capabilities provided by the system, with a description of each capability.

1. The manufacturer must explain the capabilities of the system that were declared in the implementation statement.
2. Additional capabilities (extensions) must be clearly indicated.

3. Required capabilities that may be bypassed or deactivated during installation or operation by the user must be clearly indicated.
4. Additional capabilities that function only when activated during installation or operation by the user must be clearly indicated.
5. Additional capabilities that normally are active but may be bypassed or deactivated during installation or operation by the user must be clearly indicated.

3.1.3 – System security documentation

3.1.3-A – System security

The manufacturer must provide information that enables the user to understand the security-related functions of the system and how they are to be used properly.

3.1.3-B – Access control implementation

Manufacturers must provide user documentation containing:

1. guidelines and usage instructions on implementing, configuring, and managing access control capabilities
2. an access control policy template or instructions to facilitate the implementation of the access control policy and associated access controls on the voting system
3. an access control policy under which the voting system was designed to operate and a description of the hazards of deviating from this policy
4. information on all privileged accounts included on the voting system

Discussion

Access control policy requirements include the minimum baseline policy definitions necessary for testing and implementing the voting system. The policies may be defined within the voting system or provided as guidelines in the documentation. The access control policy includes the assumptions that were made when the system was designed, the justification for the policy, and the hazards of deviating from the policy. Information on privileged accounts include the name of the account, purpose, capabilities and permissions, and how to disable the account in the user documentation.

3.1.3-C – Physical security

Manufacturers must provide user documentation explaining how to implement all physical security controls for the voting device, including model procedures necessary for effective use of countermeasures.

3.1.3-D – Audit Procedures

The manufacturer must provide information that enables the user to conduct audit procedures to determine whether tabulation is accurate.

3.1.3-E – Risk Analysis

The manufacturer must provide a report of a risk analysis for the voting system that contains a list of possible threats, risks of threat occurrence, and mitigation strategies employed by the voting system.

3.1.4 – Software Installation

3.1.4-A – Software installation

The manufacturer must provide a list of all software to be installed on the programmed devices of the voting system and the installation software used to install the software in the user documentation.

Discussion

Software to be installed on programmed devices of the voting system includes executable code, configuration files, data files, and election specific software.

3.1.4-B – Software information

The manufacturer must provide at a minimum in the user documentation the following information for each piece of software to be installed or used to install software on programmed devices of the voting system:

1. software product name
2. software version number
3. software manufacturer name
4. software manufacturer contact information
5. type of software (application logic, border logic, third party logic, COTS software, or installation software)
6. list of software documentation
7. component identifiers (such as filenames) of the software, and type of software component (executable code, source code, or data)

3.1.4-C – Software location information

The manufacturer must provide in the user documentation the location (such as full path name or memory address) and storage device (such as type and part number of storage device) where each piece of software is installed on programmed devices of the voting system.

Discussion

This requirement applies to software installed on programmed devices of the voting system. The full directory path is the final destination of the software when installed on non-volatile storage with a file system.

3.1.4-D – Election specific software identification

The manufacturer must identify election specific software in the user documentation.

3.1.4-E – Installation software and hardware

The manufacturer must provide a list of software and hardware required to install software on programmed devices of the voting system in the user documentation.

3.1.4-F – Software installation procedure

The manufacturer must document the software installation procedures used to install software on programmed devices of the voting system in user documentation.

3.1.4-G – Compiler installation prohibited

The software installation procedures used to install software on programmed devices of the voting system must result in no compilers being installed on the programmed device.

3.1.4-H – Baseline binary image creation

To replicate programmed device configurations, the software installation procedures must create a baseline binary image of the initial programmed device configuration on an unalterable storage media with a digital signature.

3.1.4-I – Programmed device configuration replication

The software installation procedures must use the baseline binary image of the initial programmed device configuration on an unalterable storage media to replicate the configuration onto other programmed devices.

3.1.4-J – Software installation record creation

The software installation procedures must specify the creation of a software installation record that includes at a minimum:

1. a unique identifier (such as a serial number) for the record
2. a list of unique identifiers of unalterable storage media associated with the record
3. the time, date, and location of the software installation
4. names, affiliations, and signatures of all people present
5. copies of the procedures used to install the software on the programmed devices of the voting system
6. the certification number of the voting system
7. list of the software installed on programmed devices of the voting system
8. a unique identifier (such as a serial number) of the vote-capture device or election management system (EMS) which the software is installed

3.1.4-K – Procurement of voting system software

The software installation procedures must specify that voting system software be obtained from test labs or distribution repositories.

Discussion

Distribution repositories provide software they receive to parties approved by the owner of the software.

3.1.4-L – Open market procurement of COTS software

The software installation procedures must specify that COTS software be obtained from the open market.

3.1.4-M – Erasable storage media preparation

The software installation procedures must specify how previously stored information on erasable storage media is removed before installing software on the media.

Discussion

The purpose of this requirement is to prepare erasable storage media for use by the programmed devices of the voting system. The requirement does not mandate the prevention of previously stored

information leakage or recovery. Simply deleting files from file systems, flashing memory cards, and removing electrical power from volatile memory satisfies this requirement.

3.1.4-N – Unalterable storage media

The software installation procedures must specify that unalterable storage media be used to install software on programmed devices of the voting system.

3.1.5 – System operations

3.1.5-A – Operations manual

The system operations manual must provide all information necessary for system use by all personnel who support pre-election and election preparation, polling place activities, and central counting activities, as applicable, with regard to all system functions and operations.

Discussion

The nature of the instructions for operating personnel will depend upon the overall system design and required skill level of system operations support personnel.

3.1.5-B – Support training

The system operations manual must contain all information that is required for the preparation of detailed system operating procedures and for the training of administrators, central election officials, election judges, and election workers.

3.1.5-C – Functions and modes

The manufacturer must provide a summary of system operating functions and modes to permit understanding of the system's capabilities and constraints.

3.1.5-D – Roles

The roles of operating personnel must be identified and related to the operating modes of the system.

3.1.5-E – Conditional actions

Decision criteria and conditional operator functions (such as error and failure recovery actions) must be described.

3.1.5-F – References

The manufacturer must also list all reference and supporting documents pertaining to the use of the system during election operations.

3.1.5-G – Operational environment

The manufacturer must identify all facilities, furnishings, fixtures, and utilities that will be required for equipment operations, including a statement of all requirements and restrictions regarding:

1. environmental protection
2. electrical service
3. recommended auxiliary power
4. telecommunications service
5. any other facility or resource required for the proper installation and operation of the system

3.1.5-H – Readiness testing

The manufacturer must provide specifications for testing system installation and readiness.

Discussion

Readiness testing refers to steps that election officials can take after configuring equipment to establish that it was correctly configured. Logic and accuracy testing would be part of this.

3.1.5-I – Features

The manufacturer must provide documentation of system operating features that includes:

1. detailed descriptions of all input, output, control, and display features accessible to the operator or voter
2. examples of simulated interactions to facilitate understanding of the system and its capabilities
3. sample data formats and output reports
4. illustration and description of all status indicators and information messages

3.1.5-J – Operating procedures

The manufacturer must provide documentation of system operating procedures that:

1. provides a detailed description of procedures required to initiate, control, and verify proper system operation
2. provides procedures that clearly enable the operator to assess the correct flow of system functions (as evidenced by system-generated status and information messages)
3. provides procedures that clearly enable the administrator to intervene in system operations to recover from an abnormal system state
4. defines and illustrates the procedures and system prompts for situations where operator intervention is required to load, initialize, and start the system
5. defines and illustrates procedures to enable and control the external interface to the system operating environment if supporting hardware and software are involved. (This information is provided for the interaction of the system with other data processing systems or data interchange protocols.)
6. provides administrative procedures and off-line operator duties (if any) if they relate to the initiation or termination of system operations, to the assessment of system status, or to the development of an audit trail
7. supports successful ballot and program installation and control by central election officials
8. provides a schedule and steps for the software and ballot installation, including a table outlining the key dates, events, and deliverables
9. specifies diagnostic tests that may be employed to identify problems in the system, verify the correction of problems, and isolate and diagnose faults from various system states

3.1.5-K – Support

The manufacturer must provide documentation of system operating procedures that:

1. defines the procedures required to support system acquisition, installation, and readiness testing
2. describes procedures for providing technical support, system maintenance, and correction of defects, and for incorporating hardware upgrades and new software releases

3.1.5-L – Transportation

The manufacturer must include any special instructions for the care and handling of voting devices and any removable media or records for

1. shipment
2. storage
3. archiving information

3.1.6 – System Maintenance

3.1.6-A – System maintenance manual

The system maintenance manual must provide information to support election workers, information systems personnel, or maintenance personnel in adjusting or removing and replacing components or modules in the field.

Discussion

Technical documentation needed solely to support the repair of defective components or modules ordinarily done by the manufacturer or software developer is not required.

3.1.6-B – General contents

The manufacturer must describe service actions recommended to correct malfunctions or problems, personnel and expertise required to repair and maintain the system, and equipment and materials facilities needed for proper maintenance.

3.1.6-C – Maintenance viewpoint

The manufacturer must describe the structure and function of the hardware, firmware, and software for election preparation, programming, vote recording, tabulation, and reporting in sufficient detail to provide an overview of the system for maintaining and identifying faulty hardware or software.

3.1.6-D – Equipment overview details

The description must include a concept of operations that fully describes such items as:

1. electrical and mechanical functions of the equipment
2. for paper-based systems, how ballot handling and reading processes are performed

3. for electronic vote-capture devices, how vote selection and ballot casting are performed
4. how data transmission over a network is performed (if applicable)
5. how data are handled in the processor and memory units
6. how data output is initiated and controlled
7. how power is converted or conditioned
8. how test and diagnostic information is acquired and used

3.1.6-E – Maintenance procedures

The manufacturer must describe preventive and corrective maintenance procedures for hardware, firmware, and software.

3.1.6-F – Preventive maintenance procedures

The manufacturer must identify and describe:

1. all required and recommended preventive maintenance tasks, including software and data backup, database performance analysis, and database tuning
2. the number and skill levels of personnel required for each task
3. the parts, supplies, special maintenance equipment, software tools, or other resources needed for maintenance
4. any maintenance tasks that must be coordinated with the manufacturer or a third party (such as coordination that may be needed for COTS used in the system)

3.1.6-G – Troubleshooting procedures

The manufacturer must provide fault detection, fault isolation, correction procedures, and logic diagrams for all operational abnormalities identified by design analysis and operating experience.

3.1.6-H – Troubleshooting procedure details

The manufacturer must identify specific procedures to be used in diagnosing and correcting problems in the system hardware, firmware, and software. Descriptions must include:

1. steps to replace failed or deficient equipment
2. steps to correct deficiencies or faulty operations in software or firmware

3. modifications that are necessary to coordinate any modified or upgraded software or firmware with other modules
4. number and skill levels of personnel needed to accomplish each procedure
5. special maintenance equipment, parts, supplies, or other resources needed to accomplish each procedure
6. any coordination required with the manufacturer, or other party, for COTS

3.1.6-I – Special equipment

The manufacturer must identify and describe any special purpose test or maintenance equipment recommended for fault isolation and diagnostic purposes.

3.1.6-J – Parts and materials

Manufacturers must provide detailed documentation of parts and materials needed to operate and maintain the system.

3.1.6-K – Approved parts list

The manufacturer must provide a complete list of approved parts and materials needed for maintenance. This list must contain sufficient descriptive information to identify all parts by:

1. type
2. size
3. value or range
4. manufacturer's designation
5. individual quantities needed
6. sources from which they may be obtained

3.1.6-L – Marking devices

The manufacturer must identify specific marking devices that, if used to make the prescribed form of mark, produce readable marked ballots so that the system meets the performance requirements for accuracy.

Discussion

Includes pens or pencils and possibly a compatible ballot marking device (BMD).

3.1.6-M – Approved manufacturers

For marking devices manufactured by multiple external sources, the manufacturer must specify a listing of sources and model numbers that satisfy these requirements.

3.1.6-N – Ballot stock specification

The manufacturer must

1. specify the required paper stock, weight, size, shape, opacity, color, watermarks, field layout, orientation, size and style of printing, size and location of vote response fields and
2. identify unique ballot styles, placement of alignment marks, ink for printing, and folding and bleed-through limitations for preparation of ballots that are compatible with the system.

3.1.6-O – Ballot stock specification criteria

User documentation for optical scanners must include specifications for ballot materials to ensure that votes are read from only a single ballot at a time, without bleed-through or transferal of marks from one ballot to another.

3.1.6-P – Printer paper specification

User documentation for voting systems that include printers must include specifications of the paper necessary to ensure correct operation, minimize jamming, and satisfy Requirement 2.1.1-E – Durability and 2.1.1-F – Durability of paper.

Discussion

This requirement covers all printers, either stand-alone or integrated with another device, regardless whether they are used for reporting, for logging, for voter verified paper records (VVPR), etc.

Prior VVSG:	Requirement Part 1:6.4.4-B and Requirement Part 1:6.5.1-A.
Related requirements:	2.1.1-E – Durability, 2.1.1-F – Durability of paper

3.1.6-Q – System maintenance, maintenance environment

The manufacturer must identify all facilities, furnishings, fixtures, and utilities that will be required for equipment maintenance.

3.1.6-R – System maintenance, maintenance support and spares

Manufacturers must specify:

1. recommended number and locations of spare devices or components to be kept on hand for repair purposes during periods of system operation
2. recommended number and locations of qualified maintenance personnel who need to be available to support repair calls during system operation
3. organizational affiliation (for example, jurisdiction, manufacturer) of qualified maintenance personnel

3.1.7 – Training material

3.1.7-A – Training manual

The manufacturer must describe the personnel resources and training required for a jurisdiction to operate and maintain the system.

3.1.7-B – Personnel

The manufacturer must specify the number of personnel and skill levels required to perform each of the following functions:

1. pre-election or election preparation functions (such as, entering an election, contest and candidate information, designing a ballot, and generating pre-election reports)
2. system operations for voting system functions performed at the polling place
3. system operations for voting system functions performed at the central count facility
4. preventive maintenance tasks
5. diagnosis of faulty hardware, firmware, or software
6. corrective maintenance tasks
7. testing to verify the correction of problems

3.1.7-C – User functions versus manufacturer functions

The manufacturer must distinguish which functions may be carried out by user personnel and which must be performed by manufacturer personnel.

3.1.7-D – Training requirements

The manufacturer must specify requirements for the orientation and training of administrators, central election officials, election judges, and election workers.

3.2 – The processes and transactions, both physical and digital, associated with the voting system are readily available for inspection.

3.2-A – Setup inspection process

The manufacturer must specify a setup inspection process that the voting device was designed to support and description of the risks of deviating from the process in the user documentation.

Discussion

The setup inspection process provides a means to inspect various properties of voting devices as needed during the election process.

3.2-B – Minimum properties included in the setup inspection process

The setup inspection process must at a minimum include

1. inspecting voting system software
2. inspecting storage locations that hold election information that changes during an election
3. inspecting other voting device properties
4. executing logic and accuracy testing related to readiness of use in an election

3.2-C – Setup inspection record generation

The setup inspection process must describe the records that result from performing the setup inspection process.

3.2-D – Installed software identification procedure

The manufacturer must provide the procedures to identify all software installed on programmed devices of the voting system in the user documentation.

Discussion

This requirement provides the ability to identify if the proper software is installed and that no other software is present on programmed devices of the voting system. This requirement covers software stored on storage media with or without a file system.

3.2-E – Software integrity verification procedure

The manufacturer must describe the procedures to verify the integrity of software installed on programmed devices of the voting system in the user documentation.

3.2-F – Election information value

The manufacturer must provide the values of voting device storage locations that hold election information that changes during the election, except for the values set to conduct a specific election in the user documentation.

3.2-G – Maximum and minimum values of election information storage locations

The manufacturer must provide the maximum and minimum values that voting device storage locations that hold election information changes during an election can store in the user documentation.

3.2-H – Variable value inspection procedure

The manufacturer must provide the procedures to inspect the values of voting device storage locations that hold election information that changes for an election in the user documentation.

3.2-I – Backup power operational range

The manufacturers must provide the nominal operational range for the backup power sources of the voting device in the user documentation.

3.2-J – Backup power inspection procedure

The manufacturer must provide the procedures to inspect the remaining charge of the backup power sources of the voting device in the user documentation.

3.2-K – Cabling connectivity inspection procedure

The manufacturer must provide the procedures to inspect the connectivity of the cabling attached to the voting device in the user documentation.

3.2-L – Communications operational status inspection procedure

The manufacturer must provide the procedures to inspect the operational status of the communications capabilities of the voting device in the user documentation.

3.2-M – Communications on/off status inspection procedure

The manufacturer must provide the procedures to inspect the on/off status of the communications capabilities of the voting device in the user documentation.

3.2-N – Quantity of voting equipment

The manufacturer must provide a list of consumables associated with the voting device, including estimated number of usages per unit in the user documentation.

3.2-O – Consumable inspection procedure

The manufacturer must provide the procedures to inspect the remaining amount of each of the voting device's consumables in the user documentation.

3.2-P – Calibration of voting device components

The manufacturer must provide:

1. a list of components associated with the voting device that require calibration
2. the nominal operating ranges for each component in the user documentation
3. the procedures to inspect the calibration of each component in the user documentation
4. the procedures to adjust the calibration of each component in the user documentation

3.2-Q – Checklist of properties to be inspected

The manufacturer must provide a checklist of other properties of the voting device to be inspected, to include:

1. a description of the risks of not performing each documented inspection
2. power sources
3. cabling for communications
4. capabilities

5. consumables
6. calibration of voting device components
7. general physical features of the voting device
8. securing external interfaces of the voting device not being used

3.3 – The public can understand and verify the operations of the voting system throughout the entirety of the election.

3.3-A – System security, system event logging

Manufacturers must provide documentation to be publicly available at no cost that:

1. describes system event logging capabilities and usage
2. fully documents the log format information

Discussion

The log format and the meaning of all possible types of log entries must be fully documented in sufficient detail to allow independent manufacturers to implement utilities to parse the log file. This documentation must be publicly available, free of charge, and not just in the TDP. The documentation may be housed by the EAC.

3.3-B – Specification of common data format usage

Voting device and system manufacturers must provide documentation to be publicly available at no cost describing how the manufacturer has implemented a NIST CDF specification for a particular device or function. This includes such items as:

1. descriptions of how elements and attributes are used
2. constraints on data elements
3. extensions as well as any constraints

Discussion

Conformance to a common data format does not guarantee data interoperability. The manufacturer needs to document fully how it has interpreted and implemented a NIST CDF specification for its voting devices and the types of data exchanged or exported.

3.3-C Bar and other codes

The voting system's documentation must provide documentation to be publicly available at no cost that fully specifies the barcode or other encoding standards or algorithms used on ballots or audit material.

Discussion

The voting system documentation needs to include the name and version of the standard used for barcodes or for any other codes that encode information that the public sees on ballots or other material that can be used in audits or verification of the election.

3.3-D Encodings

The voting system's documentation must provide documentation to be publicly available at no cost that fully specifies any compression, packing, or otherwise encodings of data used on ballots, including how data may be compressed or otherwise altered prior to encoding within a barcode.

Discussion

The voting system documentation needs to include the name and version of the standard used for barcodes or for any other codes that encode information that the public sees on ballots or other material that can be used in audits or verification of the election. The documentation also needs to include how the data may be packed or compressed within the encoding. The report should be sufficient for a voter to understand the barcoded contents and for an auditor to develop applications that examine the barcoded contents.

3.3-E Ballot selection codes

The voting system must be capable of producing a report to be publicly available at no cost to show the meaning of codes and other data used within a barcode to represent ballot selections and ballot style information.

Discussion

Codes are commonly used with barcodes that represent a voter's ballot selections. The codes are meaningless to a voter or an auditor unless the voting system can produce a report that shows all codes possible and what contests and ballot selections they represent. If, for example, a code of 90 is used to represent a particular contest, then the report must show that 90 refers to the title or description of that particular contest. This includes other information within the barcode generally found on clear-text ballots to identify the ballot style.

Principle 4
Interoperable

The voting system is designed to support interoperability in its interfaces to external systems, its interfaces to internal components, its data, and its peripherals.

4.1 - Voting system data that is imported, exported, or otherwise reported, is in an interoperable format.

4.2 - Standard, publicly-available formats for other types of data are used, where available.

4.3 - Widely-used hardware interfaces and communications protocols are used.

4.4 - Commercial-off-the-shelf (COTS) devices can be used if they meet applicable VVSG requirements.

Principle 4
INTEROPERABLE

The voting system is designed to support interoperability in its interfaces to external systems, its interfaces to internal components, its data, and its peripherals.

This Principle covers requirements that ensure all system data is in an interoperable format and explains when standard, publicly available formats are used. It also addresses widely used hardware interfaces and when COTS devices are permitted. The Guidelines under Principle 4 are:

1 - Interoperable format requirements, which include voting system data that is imported, exported, or otherwise reported.

2 - Standard formats covering when publicly available formats for other types of data not addressed by NIST CDF specifications can be used.

3 - Interfaces and communication protocols, describing the need to use standard hardware interfaces and communication protocol when connecting devices.

4 - COTS covering the requirement that any COTs devices used meet all applicable requirements.

4.1 – Voting system data that is imported, exported, or otherwise reported, is in an interoperable format.

4.1-A – Data export and exchange format

Voting devices must include support for the NIST SP Common Data Format (CDF) specifications for data inputs and output:

1. Election programming and results reporting data, NIST SP 1500-100
2. Election event logging data, NIST SP 1500-101
3. Cast vote records, NIST SP 1500-102
4. Voter registration-related data, NIST SP 1500-104

Discussion

Manufacturers can use proprietary data formats but need to also include support for the NIST CDF specifications. Implementations that do this using translations or conversions from a proprietary format would be considered in conformance.

4.1-B – Election programming data input and output

Election definition processes must include support for the NIST CDF specifications regarding:

1. Import and export of election programming data
2. Import and export of ballot programming data

Discussion

This requirement concerns import and export of pre-election data into an election definition device, such as for identification of political geography, contest, candidate, ballot data, and other pre-election information used to setup an election and produce ballots. This also includes reports of pre-election data from the election definition device that can be used to verify the election programming setup.

Applies to: election definition

4.1-C – Tabulator report data

Tabulation processes must include support for the NIST CDF specifications for import and export of election results reporting data.

Discussion

Importing results data is required so as to provide support for aggregations of vote data from different election management systems such as what occurs during state roll-ups on election night and during the process of election results certification.

External reference: URL to SP 1500-100, 102
Applies to: tabulation, reporting

4.1-D – Exchange of cast vote records (CVRs)

Casting, tabulation, and audit processes that use CVRs must include support for the NIST CDF specifications for export and import of those records.

Applies to: casting, tabulation, audit

Discussion

Devices that export or import CVRs typically include voter-facing and batch-fed scanners, election management systems, and other devices used for adjudication or auditing.

4.1-E – Exchange of voting device election event logs

The voting devices comprising the voting system must include support for the NIST CDF specifications for import or export of election event log data.

Discussion

This requirement refers to election event logs and not system logs provided by common operating systems such as Microsoft Windows or Apple IOS. This requirement does not mandate that manufacturers use the format for storing election log information; a manufacturer can meet this requirement by conversion or translation from a native format into the CDF.

4.1-F – Voting device event code documentation

Voting device and system manufacturers must include a specification for event codes used in their equipment and make this available upon request.

Discussion

Use of SP 1500-101 for election event logs only addresses the data format; it does not mandate a common lexicon for event codes. SP 1500-101 provides a separate schema for including documentation of event codes; manufactures may make this available publicly or upon request without condition.

4.1-G – Specification of common format usage

Voting device and system manufacturers must include a specification describing how the manufacturer has implemented a NIST CDF specification for a particular device or function. This includes such items as descriptions of how elements and attributes are used, as well as any constraints or extensions.

Discussion

Conformance to a common data format does not guarantee data interoperability. The manufacturer needs to document fully how it has interpreted and implemented a NIST CDF specification for its voting devices and the types of data exchanged or exported.

4.2 - Standard, publicly-available formats for other types of data not addressed by NIST CDF specifications are used.

4.2-A – Standard formats

Standard, publicly-available, and publicly-documented formats must be used, where possible, for exchanging data or encoding data.

Discussion

Examples include the use of common data encodings such as bar or QR codes.

4.2-B – Public documented manufacturer formats

Where it is not possible to meet requirement 4.1-A, manufacturers must include a publicly documented specification that describes the protocol or data format.

Discussion

As an example, a manufacturer's algorithm or method for packing or compressing of data before encoding in a QR code will be documented so that its implementation and usage is available publicly.

4.3 - Widely-used hardware interfaces and communications protocols are used.

4.3-A – Standard device interfaces

Standard, common hardware interfaces and protocols must be used to connect devices.

Discussion

Examples include using published communications protocols, such as, IEEE, and using common hardware interfaces, such as, USB, when connecting to printers, disks, and other devices.

4.4 - Commercial-off-the-shelf (COTS) devices can be used if they meet all applicable VVSG requirements.

4.4-A – COTS devices meet applicable requirements

COTS devices, if used, must satisfy all applicable VVSG requirements.

Discussion

As an example, use of a COTS scanner to scan ballots is potentially possible, but there needs to be associated software to interpret the voter marks, create a cast vote record, and include support for the NIST CVR CDF. Together, the COTS scanner and associated software will meet applicable requirements for casting, counting, reporting, etc.

Principle 5
Equivalent and Consistent

All voters can access and use the voting system regardless of their abilities, without discrimination.

5.1 - Voters have a consistent experience throughout the voting process within any method of voting.

5.2 - Voters receive equivalent information and options in all modes of voting.

Principle 5
EQUIVALENT AND CONSISTENT VOTER ACCESS

All voters can access and use the voting system regardless of their abilities, without discrimination.

Principle 5 ensures that all voters can cast their votes easily and accurately, regardless of any disabilities they may have. This fulfills the requirements of the Help America Vote Act (HAVA), Section 301(a)(3) which states, "The voting system shall (A) be accessible for individuals with disabilities, including nonvisual accessibility for the blind and visually impaired, in a manner that provides the same opportunity for access and participation (including privacy and independence) as for other voters."

It also addresses Section 508 of the Rehabilitation Act (amended in 1998) which requires that electronic and information technology be accessible to people with disabilities, and the language access requirements in the Voting Rights Act (VRA)

The goal of both guidelines in Principle 5 is to ensure that everyone can use the voting system, regardless of their abilities or preferences. Voting equipment can present ballot choices in a variety of ways which make it possible for people with a wide range of disabilities to vote. The equipment must also fully support all the languages that the manufacture claims to support. The big differences are that Guidelines:

1 – Consistent experience also covers the requirement that all vote records must be auditable by those who speak only English. And, in addition to actually casting their votes, people must have access to those same modes of presentation for all information and instructions related to casting those votes.

2 – Equivalent information also addresses the requirement that these modes of presentation (visual, audio, enhanced video) or interaction (touch, tactile, non-manual) must offer consistent and equivalent support for the actions required to vote, and offer them in a way that does not introduce bias. In addition, if the voter switches modes mid-stream, for example from video to audio mode or from Spanish to English, the system must preserve all settings and votes cast.

Finally, note that this principle's requirements, including supporting the interaction modes listed in 5.1-A, also apply to all of the usability and accessibility requirements in Principles 6-8.

5.1 – Voters have a consistent experience throughout the voting process within any method of voting.

5.1-A – Voting methods and interaction modes

Within any method of voting, all interaction modes including audio, tactile, enhanced visual, and non-manual must have the same capabilities as the visual interaction mode including ballot activation, voting, verification, and casting.

Discussion

Methods of voting that a voting system might support include in-person voting, vote-by-mail, remote ballot marking, among others. For voting systems to meet this requirement they would need to include (among others):

- Features that support non-manual interaction enable voters with limited dexterity, that is those who lack fine motor control or the use of their hands, to submit their ballots privately and independently without manually handling the ballot.
- Features for paper ballots or paper verification records that assist voters with poor reading vision to read these ballots and records.
- Features to allow blind voters and voters with limited dexterity to perform paper-based verification, or feed their own optical scan ballots into a reader, if all other voters do so. For example, ballot papers or smart cards might provide tactile cues that allow the correct insertion of the card.
- Support for all voting variations. For example, if a visual ballot supports voting a straight party ticket and then changing the vote for a single contest, so do all other interaction modes.

External reference: WCAG 2.0/Section 508

Prior VVSG sources: VVSG 1.1 - 3.2.5g, 3.3.3.b.i, 3.3.3.d, 3.3.3.e, 3.3.4.b, 3.3.8

5.1-B – Languages

The voting system must be capable of displaying, printing, and storing the ballot, contest options, review screens, vote verification records, and voting instructions in all languages the manufacturer has declared the system supports, in both visual and audio formats.

Discussion

Both written and unwritten languages are within the scope of this requirement.

The system will be tested in all languages that the manufacturer claims it is capable of supporting.

External reference: VRA

Prior VVSG sources: VVSG 1.1 - 3.2.7.a, 7.8.6.c, 7.8.6,ci, 7.8.6.cii

5.1-C – Vote records

All records, including paper ballots and paper verification records, must have the information required to support auditing by election workers and others who can read only English.

Discussion

Although the system needs to be easily usable by voters using an alternative language, records of the vote also need to be fully available to English-only readers for auditing purposes. Additional information, such as precinct and election identifiers may be in English to support election administration and auditing.

To meet this requirement, a paper ballot may not be a fully bilingual ballot. For instance, the full text of a ballot question might appear only in the alternative language, but the contest option (for example, "yes / no") needs to be readable by English-only readers.

Prior VVSG source: VVSG 1.1 - 3.2.7.a.iii

5.1-D – Accessibility features

Accessibility features must be integrated into the manufacturer's voting system so accessibility for voters with disabilities is supported throughout the voting session, including any steps to activate the ballot at the voting station, ballot marking, verification, and casting.

Discussion

This requirement ensures accessibility to the voter throughout the entire session. Not only are individual system components (such as ballot markers, paper records, and optical scanners) accessible, but they also work together to support voters with disabilities.

External Reference: HAVA

Prior VVSG source: VVSG 1.1 - 3.3.1.a

5.1-E – Reading paper ballots

If the voting system generates a paper record (or some other durable, human-readable record) that can be the official ballot or determinative vote record, then the voting system must allow the voter to verify the paper record using the same access features they used to mark the ballot, including audio, tactile, enhanced visual, and non-manual.

Discussion

Paper records present difficulties for voters who use large font, high contrast, alternative languages, and other settings. The purpose of this requirement is to ensure that all voters have a similar opportunity for vote verification.

This requirement allows the voter to use the same access features throughout the entire voting session. It also does not preclude the voter from choosing a different access feature to verify the record. For example, the voting system might provide a reader that converts the paper record contents into audio output.

External reference:	HAVA
Prior VVSG sources:	VVSG 1.1 - 3.3.1.e, 3.2.2.1.g, 7.8.7.b
Related requirement:	7.1-I Text size (paper)

5.1-F – Accessibility documentation

As part of the overall system documentation the manufacturer must include descriptions and instructions for all accessibility features that describe:

- recommended procedures that fully implement accessibility for voters with disabilities, and
- how the voting system supports those procedures.

Discussion

The purpose of this requirement is for the manufacturer not simply to deliver system components, but also to describe the accessibility scenarios they are intended to support, so that election offices have the information they need to effectively make accessibility features available to voters with disabilities.

External reference:	WCAG 2.0 /Section 508
Prior VVSG source:	VVSG 1.1 - 3.3.1.a.i
Related requirements:	7.3-N - Instructions for voters 7.3-O - Instruction for election workers

5.2 – Voters receive equivalent information and options in all modes of voting.

5.2.A – No bias

The voting system must not introduce bias for or against any of the contest options presented to the voter. In audio, tactile, enhanced visual, and non-manual modes, all ballot options are to be presented in an equivalent manner.

Discussion

Certain differences in presentation are mandated by state law, such as the order in which candidates are listed and provisions for voting for write-in candidates. This requirement ensures that comparable characteristics such as font size or audio volume and speed are the same for all ballot options.

Prior VVSG source: VVSG 1.1 - 3.2.4.d

5.2-B – Presenting content in all languages

All information that is presented in English must also be presented in all other languages that are supported, whether the language is in visual or audio format. This includes instructions, warnings, messages, notification of undervotes or overvotes, contest options, and vote verification information.

Discussion

It is not sufficient simply to present the ballot options in the alternative languages. All the supporting information voters need to mark their ballot is also covered in this requirement.

External reference: VRA

Prior VVSG source: VVSG 1.1 - 3.2.7.a.ii

5.2-C – Information in all modes

Instructions, warnings, messages, notifications of undervotes or overvotes, and contest options must be presented to voters in the interaction modes required in **5.1-A – Interaction modes** for all functions. This includes ballot activation, voting, verification, and casting.

Discussion

Examples of how to meet this requirement in the audio format include:

- An audio that includes cues to help users know what to expect. For example, announcing the number of items in a list of candidates or contests makes it easier to jump from one item to another without waiting for the audio to complete.
- Audio cues that also ensure the voter is aware of possible undervotes or overvotes.

External reference: WCAG 2.0/Section 508
Prior VVSG source: VVSG 1.1 - 3.3.1.b

5.2-D – Audio synchronized

The voting system must provide the option for synchronized audio output to convey the same information that is displayed visually.

Discussion

This requirement covers all information, including information entered by the voter such as write-in votes.

This requirement applies to any audio output, whether it is recorded or generated as text-to-speech.

Any differences between audio and visual information are for functional purposes only, with variations only based on differences in the interaction mode, especially for instructions.

This feature can assist voters with cognitive disabilities.

External reference: WCAG 2.0/Section 508
Prior VVSG source: VVSG 1.1 - 3.3.2.c

5.2-E – Sound cues

Sound and visual cues must be coordinated so that:

- Sound cues are accompanied by visual cues unless the system is in audio-only mode.
- Visual cues are accompanied by sound cues, unless the system is in visual-only mode.

Discussion

The voting equipment might beep if the voter attempts to overvote. If so, there has to be an equivalent visual cue, such as the appearance of an icon or a blinking element. If the voting system has been set to audio-only mode, there would be no visual cue.

Audio output also supports non-written languages, voters with low literacy, or voters with low vision.

External reference: WCAG 2.0/Section 508
Prior VVSG source: VVSG 1.1 - 3.3.6.b

5.2-F – Preserving votes

The voting system must allow the voter to switch among all modes including audio, tactile, enhanced visual, and non-manual, and change languages at any time during the voting session while preserving the current votes. When switching mode or language, the system will also preserve navigation, screen position, visual settings, audio settings, and other information within and across contests.

Discussion

A voter who initially chooses an English version of the ballot might switch to another language in order to read a referendum question.

Many blind voters have preferences for audio settings, including the rate of speech and volume that are important for comprehension.

Changing visual settings for text size might change the layout of the information on the screen, making it important to maintain the screen position.

External reference:	WCAG 2.0/Section 508
Prior VVSG sources:	VVSG 1.1 - 3.3.2.c.ii, 3.3.2.a, 3.2.7.a.i, 3.3.3.c.v, 3.3.3.c.vii, 3.3.6.a

Principle 6
Voter Privacy

Voters can mark, verify, and cast their ballot privately and independently.

6.1 - The voting process preserves the privacy of the voter's interaction with the ballot, modes of voting, and vote selections.

6.2 - Voters can mark, verify, and cast their ballot or other associated cast vote record, without assistance from others.

Principle 6
VOTER PRIVACY

Voters can mark, verify, and cast their ballot privately and independently.

Privacy for voters refers to the property of a voting system that is designed and deployed to enable voters to obtain a ballot, and mark, verify, and cast it without revealing their ballot selections or selections of language, display, and interaction modes to anyone else.

Privacy covers:

- electronic and paper interfaces,
- audio and video systems, and
- warning systems that must also preserve confidentiality.

Principle 6: Voter Privacy, covers voter privacy during voting. Requirements in Principle 6 help ensure private and independent voting as mandated in the Help America Vote Act (HAVA).

The related Principle 10: Ballot Secrecy covers preventing links between a voter and a ballot after the ballot has been cast.

The Guidelines under Principle 6 cover:

1 – Privacy of interaction which describes the requirement that the voting process preserves the privacy of the voter's interaction with the ballot, modes of voting and vote selections

2 – Voting without assistance which mandates that voters can mark, verify, and cast their ballot or other cast vote record without assistance from others.

6.1 - The voting process preserves the privacy of the voter's interaction with the ballot, modes of voting, and vote selections.

6.1-A – Preserving privacy for voters

Privacy for voters must be preserved during the entire voting session including ballot activation, voting, verifying, and casting the ballot.

Discussion

This requirement allows for different approaches for electronic and paper interfaces.
In both cases, appropriate shielding of the voting station is important -- for example, privacy screens for the voting stations.

When a paper record with ballot information needs to be transported by the voter, devices such as privacy sleeves can be necessary. This requirement applies to all records with information on votes (such as a vote verification record) even if that record is not itself a ballot.

External reference:	HAVA
Prior VVSG source:	VVSG 1.1 - 7.8.5.a, 3.2.3.1.b
Related requirements:	7.2-F – Voter speech

6.1-B – Warnings

During a voting session the voting system must issue all warnings in a way that preserves privacy for voters and the confidentiality of the ballot.

Discussion

HAVA 301 (a)(1)(C) mandates that the voting system notifies the voter of an attempted overvote in a way that preserves privacy for voters and the confidentiality of the ballot. This requirement addresses that mandate.

External reference:	HAVA
Prior VVSG source:	VVSG 1.1 - 3.2.3.1.d
Related requirements:	7.3-K– Warnings, alerts, instructions

6.1-C – Enabling or disabling output

During a voting session the voting system must make it possible for the voter to independently enable or disable either the audio or the video output and be notified of the change, resulting in a video-only or audio-only presentation.

Discussion

Voters can be notified of the change to the display or audio output in a variety of ways including beep, voice, or visual notification. An unobtrusive notification that the system has changed the visual display mode is helpful to voters who cannot see the screen to confirm the change visually.

External reference:	WCAG 2.0/Section 508
Prior VVSG source:	VVSG 1.1 - 3.3.2.c.i
Related requirements:	7.2-A – Display and interaction options 7.3-K – Warnings, alerts, instructions

6.1.D – Audio privacy

Audio during the voting session must be audible only to the voter.

Discussion

Voters who are hard of hearing but need to use an audio interface sometimes need to increase the volume of the audio. Such situations require headphones or other devices (such as a hearing loop) with low sound leakage so the contents of the audio cannot be overheard and understood by others.

Voters who are hard of hearing can share audio interfaces with their designated assistants.

External reference:	WCAG 2.0/Section 508
Prior VVSG source:	3.2.3.1.c
Related requirements:	7.2-F – Voter speech 8.1-J – Hearing aids

6.2 - Voters can mark, verify, and cast their ballot or other associated cast vote record without assistance from others.

6.2-A - Voter Independence

Voters must be able to mark, verify, and cast their ballot or other associated cast vote records independently and without assistance from others.

1. If a voting system includes any features voters might use after casting a ballot, they must be accessible.

Discussion

This requirement ensures that voters can vote with their own interaction preferences and without risk of intimidation or influence.

HAVA 301 (a)(1)(C) mandates that the voting system be accessible for individuals with disabilities, including nonvisual accessibility for the blind and visually impaired, in a manner that provides the same opportunity for access and participation (including privacy and independence) as for other voters. This requirement directly addresses this mandate.

Examples of features for voters after casting their ballot include E2E system ballot tracking features, forms or notices to cure problems with a vote-by-mail ballot, and sites to learn whether a provisional ballot was accepted for counting.

External reference:	HAVA
Prior VVSG source:	7.8.5.a, 3.2.3.1.b
Related requirements:	5.1-D – Accessibility features 5.1-E – Reading paper ballots 2.2-A – User-centered design process.

Principle 7
Marked, Verified, and Cast as Intended

Ballots and vote selections are presented in a perceivable, operable, and understandable way and can be marked, verified, and cast by all voters.

7.1 - The default voting system settings present a ballot usable for the widest range of voters, and voters can adjust settings and preferences to meet their needs.

7.2 - Voters and election workers can use all controls accurately, and voters have direct control of all ballot changes and selections.

7.3 - Voters can understand all information as it is presented, including instructions, messages from the system, and error messages.

Principle 7
MARKED, VERIFIED, AND CAST AS INTENDED

Ballots and vote selections are presented in a perceivable, operable, and understandable way and can be marked, verified, and cast by all voters.

This principle covers the core actions of voting, supporting voters in marking, verifying, and casting their ballot. It includes all voting systems including both paper ballots and electronic interfaces.

The requirements in P-7 are derived from federal laws, including:

- the Help America Vote Act (HAVA),
- Section 508 (part of the Rehabilitation Act of 1973)
- Web Content and Accessibility Guidelines (WCAG), and,
- the Voting Rights Act.

This principle is divided into three sections which follow 508/ WCAG's well-known organizing principles of Perceivable, Operable, and Understandable. Robust, the final POUR principle is included in Principle 8 – *Robust, safe, usable and accessible*. The Guidelines under Principle 7 are:

1 – Default settings covers how ballot information is presented using audio and visual settings, as well as the voter's ability to adjust the voting system to meet their needs or preferences. This includes using color and contrast, adjusting font size, and ensuring audio settings result in understandable speech.

2 – Controls covers a voter's operation of the voting system, that is, the interaction with and control of the ballot during voting, including how the information is displayed and the voter's ability to navigate the system. It addresses the voter's ability to scroll though the electronic ballot, use the audio and touch controls, and use simple gestures. It also includes the need for adequate space for those who use wheelchairs. Both voters and election workers must be able to use all controls accurately.

3 – Understandable information covers the ability of the voter to understand all information on the ballot as it is presented, including instructions and messages from the system. Among other elements, it includes preventing contest layouts that can cause confusion, making clear the maximum number of choices a voter has, notifying the voter of any errors on the ballot (such as overvotes) before it is cast, and letting the voter know when they have successfully voted. It also covers ensuring that instructions for election workers are understandable.

7.1 – The default voting system settings present a ballot usable for the widest range of voters, and voters can adjust settings and preferences to meet their needs.

7.1-A – Reset to default settings

If the adjustable settings of the voter interface have been changed by the voter or election worker during the voting session, the system must automatically reset to the default setting when the voter finishes voting, verifying, and casting.

Discussion

This ensures that the voting system presents the same initial appearance to every voter.

This requirement covers all settings that can be adjusted, including font size, color, contrast, audio volume, rate of speech, turning on or off audio or video, and enabling alternative input devices.

External reference:	WCAG 2.0/Section 508
Prior VVSG source:	VVSG 1.1 - 3.2.5.b
Related requirement:	7.1-K – Audio settings
Applies to:	Electronic interfaces

7.1-B – Reset by voter

If either the voter or an election worker can adjust the settings of the voter interface, there must be a way for the voter to restore the default settings while preserving the current votes.

Discussion

This requirement allows a voter or election worker who has adjusted the system to an undesirable state to reset all settings and start over.

External reference:	WCAG 2.0/Section 508
Prior VVSG source:	VVSG 1.1 - 3.2.5.c
Related requirement:	5.2F – Preserving votes
Applies to:	Electronic interfaces

7.1-C – Default contrast

The default contrast ratio must be at least 10:1 for all elements that visually convey information such as text, controls, and infographics or icons.

1. For electronic displays for voters and election workers, this is measured as a luminosity contrast ratio between the foreground and background colors of at least 10:1.
2. For paper ballots and other paper records, the contrast ratio will be at least 10:1 as measured based on ambient lighting of at least 300 lx.

Discussion

For example, this applies to:

- candidate names,
- a broken arrow,
- the outline of an oval, circle, or rectangular target used to mark voter selections, or
- informational icons identifying voter selections or other information.

Purely decorative elements that do not communicate meaning do not have to meet this requirement.

A 10:1 luminosity contrast ratio provides enough difference between the text and background to enable people with most color vision deficiencies to read the ballot. This is higher than the highest contrast requirements of 7:1 in WCAG 2.0 Checkpoint 1.4.6 (Level AAA) to accommodate a wider range of visual disabilities. There are many free tools available to test color luminosity contrast using the WCAG 2.0 algorithm.

External reference:	WCAG 2.0/Section 508
Prior VVSG source	VVSG 1.1 - 3.2.2.2.f.ii, 3.2.5.h, 3.2.5.h.i, 3.2.5.h.ii
Applies to:	Electronic interfaces

7.1-D – Contrast options

The voting system must provide options for high and low contrast displays, including the alternative display contrast options as listed below:

1. A high contrast option with a white background and dark text, with a luminosity contrast ration of at least 20:1
2. A high contrast option with a black background (between #000000 and #111111) and one of the following foreground options:
    a. Yellow text similar to #FFFF00, providing a contrast ratio of at least 17.5:1
    b. Cyan text similar to #00FFFF, providing a contrast ratio of at least 15:1
    c. White text similar to #FAFAFA, providing a contrast ratio of at least 18:1

1. A low contrast option, providing a contrast ratio in the range of 4.5:1 to 8:1

Discussion

This requirement for options for the overall display contrast ensures that there is an option for the visual presentation for people whose vision requires either high or low contrast.

High and low contrast options apply to the entire screen, including decorative elements.

Examples of color combinations for a low contrast options include:

- Brown text similar to #BB9966 on a black background (7.8:1)
- Black text on a background with text similar to #BB9966 (7.8:1)
- Grey text similar to #6C6C6C on a white background (5.2:1)
- Grey/brown text similar to #97967E on a black background (6.9:1)
- Grey text similar to #898989 on a dark background similar to #222222 (4.5:1)

External reference: WCAG 2.0/Section 508
Prior VVSG source: VVSG 1.1 - 3.3.2.a.i, 3.2.5.h.ii
Applies to: Electronic interfaces

7.1-E – Color conventions

The use of color by the voting system must follow these common conventions:

1. Green, blue, or white is used for general information or as a normal status indicator
2. Amber or yellow is used to indicate warnings or a marginal status
3. Red is used to indicate error conditions or a problem requiring immediate attention

External reference: WCAG 2.0/Section 508
Prior VVSG source: VVSG 1.1 - 3.2.4.f

7.1-F – Using color

Color coding must not be used as the only means of communicating information, indicating an action, prompting a response, distinguishing a visual element, or providing feedback on voter actions or selections.

Discussion

While color can be used for emphasis, some other non-color mode is also needed. This could include shape, lines, words, text, or text style. For example, an icon for “stop” can be red enclosed in an octagon shape. Or, a background color can be combined with a bounding outline and a label to group elements on the ballot.

External reference: WCAG 2.0/Section 508
Prior VVSG source VVSG 1.1 - 3.2.5.i

7.1-G – Text size (electronic display)

A voting system's electronic display must be capable of showing all information in a range of text sizes that voters can select from, with a default text size at least 4.8 mm (based on the height of the uppercase I), allowing voters to both increase and decrease the text size.

The voting system may meet this requirement in one of the following ways:

1. Provide continuous scaling with a minimum increment of 0.5 mm that covers the full range of text sizes from 3.5 mm to 9.0 mm.
2. Provide at least four discrete text sizes, in which the main ballot options fall within one of these ranges.

    a) 3.5-4.2 mm (10-12 points)
    b) 4.8-5.6 mm (14-16 points)
    c) 6.4-7.1 mm (18-20 points)
    d) 8.5-9.0 mm (24-25 points)

Discussion

The text size requirements have been updated from the VVSG 1.1 requirement to better meet the needs of voters who need larger text, including older voters, voters with low literacy, and voters with some cognitive disabilities.

This requirement also fills a gap in the text sizes required in VVSG 1.1 which omitted text sizes needed or preferred by many voters. Although larger font sizes assist most voters with low vision, certain visual disabilities such as tunnel vision require smaller text.

The sizes are minimums. These ranges are not meant to limit the text on the screen to a single size. The text can fall in several of these text sizes. For example, candidate names or voting options might be in the 4.8-5.6 mm range, secondary information in the 3.5-4.2 mm range, and titles or button labels in the 6.4-7.1 mm range.

The default text size of 4.8 mm is based on "**Information and Communication Technology (ICT) Final Standards and Guidelines**" (36 CFR Parts 1193 and 1194, RIN 3014-AA37, published in the Federal Register on January 18, 2017)

External reference:	WCAG 2.0/Section 508
Prior VVSG source:	VVSG 1.1 - 3.2.5.d, 3.2.5.e
Related requirements:	5.2-A – No bias 5.2-F – Preserving votes 7.2-D – Scrolling 7.3-B – No split contests
Applies to:	Electronic interfaces

7.1-H – Scaling and zooming (electronic display)

When the text size is changed, all other information in the interface, including informational icons, screen titles, buttons, and ballot marking target areas, must change size to maintain a consistent relationship to the size of the text. Informational elements in the interface do not have to be scaled beyond the size of the text.

1. When the text is enlarged up to 200% (or 7.1 mm text size), the ballot layout must adjust so that there is no horizontal scrolling or panning of the screen.
2. When the text is enlarged more than 200%, there may be horizontal scrolling or panning if needed to maintain the layout of the ballot and a consistent relationship between the text for ballot options and associated marking targets.

Discussion

The intention of this requirement is that all of the informational elements of the interface change size in response to the text size. However, some interface designs include elements that are already large enough that making them larger would distort the layout. In this case, this does not require those elements to grow proportionately beyond the size of the text.

Techniques for managing scaling and zooming an electronic interface while adjusting the layout to fit the new size are sometimes called responsive design or responsive programming.

This requirement does not preclude novel approaches to on-screen magnification such a zoom lens showing an enlarged view of part of a screen (as long as it meets the requirements in 7.2 for the operability of the controls).

This requirement follows WCAG 2.0 in requiring scaling with no horizontal scrolling up to 200% and allowing zooming with horizontal scrolling for larger text.

External reference:	WCAG 2.0/Section 508
Related requirements:	7.1-G – Text size (electronic display) 7.2-D – Scrolling 5.1-A- – Interaction modes 5.2-A – No Bias 5.2-C – All information in all modes 5.2-F – Preserving votes
Applies to:	Electronic interfaces

7.1-I – Text size (paper)

The voting system must be capable of printing paper ballots and other paper records with a minimum font size of 3.5 mm (10 points).

Discussion

Although the system can be capable of printing in several font sizes, local or state laws and regulations can also govern the use of various font sizes.

If the voting system includes a large-print display option, a good range for the text size is 6.4-7.1 mm matching the size in ***7.1-G-Text size (electronic display)***

If typography changes such as text size or display style are used to differentiate languages on a multi-lingual ballot, the requirements in **5.2-A-No bias** (and relevant state election law for ballot design) still apply.

Prior VVSG source:	VVSG 1.1 - 3.2.5.i
Related requirements:	5.1-E – Reading paper ballots 7.1-G – Text size (electronic display)
Applies to:	Printed Material

7.1-J – Sans-serif font

The voting system must be capable of presenting text intended for the voter in a sans-serif font.

Discussion

This requirement ensures that systems are capable of best practice while allowing them to also meet local or state laws or regulations that might differ.

In general, sans-serif fonts are easier to read on-screen, look reasonably good when their size is reduced, and tend to retain their visual appeal across different platforms. Examples of sans-serif fonts with good readability characteristics include Arial, Calibri, Microsoft Tai Le, Helvetica, Univers, Clearview ADA, or Open Sans.

"**Information and Communication Technology (ICT) Final Standards and Guidelines**" (36 CFR Parts 1193 and 1194, RIN 3014-AA37, published in the Federal Register on January 18, 2017) requires that at least one mode of characters displayed on the screen be a sans-serif font.

The guidance on suitable fonts replaces the detailed text characteristics in VVSG 1.1

External reference:	WCAG 2.0/Section 508
Prior VVSG sources:	VVSG 1.1 - 3.2.5.f, 3.2.5.d

7.1-K – Audio settings

The voting system's audio format interface must meet the following requirements:

1. The settings for volume and rate of speech are followed regardless of the technical means of producing audio output.
2. The default volume for each voting session is set between 60 and 70 dB SPL.

3. The volume is adjustable from a minimum of 20dB SPL up to a maximum of 100 dB SPL, in increments no greater than 10 dB.
4. The rate of speech is adjustable throughout the voting session while preserving the current votes, with 6 to 8 discrete steps in the rate.
5. The default rate of speech is 120 to 125 words per minute (wpm).
6. The range of speech rates supported is from 60-70 wpm to 240-250 wpm (or 50% to 200% of the default rate), with no distortion.
7. Adjusting the rate of speech does not affect the pitch of the voice.

Discussion

The top speech rate is slower than some audio users prefer for narrative reading to ensure that candidate names are pronounced clearly and distinctively.

Note that calculation of rate of speech can vary based on the length of the words in the sample, so requirements are stated as a small range.

Speech rates as slow as 50 wpm and as fast as 300 wpm can be included if this can be done without distortion or flanging.

This requirement is intended to be tested using "real ear" measurements not simply measurements at the point of the audio source.

According to an explanation written by the Trace Center (**http://trace.umd.edu/docs/2004-About-dB)**, 60 dB SPL is the volume of ordinary conversation.

FCC regulations for hearing aids, 47 CFR Parts 20 and 68: Hearing Aid Standard, includes useful information about how to test audio volume and quality.

External reference:	WCAG 2.0/Section 508
Prior VVSG source:	VVSG 1.1 - 3.3.3.c.iv
Related requirements:	7.1-A – Reset to default settings

7.1-L – Speech frequencies

The voting system's audio format interface must be able to reproduce frequencies over the audible speech range of 315 Hz to 10 KHz.

Discussion

The required frequencies include the range of normal human speech. This allows the reproduced speech to sound natural.

This is a requirement for the capability of the system so that it is possible to create intelligible audio. It is not a requirement for a ballot in a real election, which is outside of the scope of the VVSG.

External reference:	WCAG 2.0/Section 508
Prior VVSG source	VVSG 1.1 - 3.3.3.c.vi

7.1-M – Audio comprehension

The voting system's audio format interface must be capable of presenting audio content so that it is comprehensible to voters who have normal hearing and are proficient in the language with:

1. proper enunciation, normal intonation, accurate pronunciation in the context of the information, and the capability to pronounce candidate names as intended
2. low background noise
3. recording or reproduction in dual-mono, with the same audio information in both ears.

Discussion

This requirement covers both recorded and synthetic speech. It applies to those aspects of the audio content that are inherent to the voting system or that are generated by default. To the extent that election officials designing the ballot determine the audio presentation, it is beyond of the scope of this requirement.

Support for non-written languages and low literacy includes audio output that is usable by voters who can see the screen.

The International Telecommunications Union (ITU) provides a set of freely available test signals for testing audio quality in Rec. ITU-T P.50 Appendix I (http://www.itu.int/net/itu-t/sigdb/genaudio/AudioForm-g.aspx?val=1000050)

External reference:	WCAG 2.0/Section 508 ITU-T P.50 Appendix I
Prior VVSG source:	VVSG 1.1 - 3.3.3.c.vii

7.1-N – Tactile keys

Mechanically operated controls, buttons, keys, or any other hardware interfaces (including dual switches or sip-and-puff devices) on the voting system available to the voter must**:**

1. be tactilely discernible without activating those controls or keys
2. include a Braille label if there is a text label
3. not require sequential, timed, or simultaneous presses or activations, unless using a full keyboard.

Discussion

A blind voter can operate the voting system by “feel” alone. This means that vision is not necessary for such operations as inserting a smart card or plugging into a headphone jack.

Controls that are distinguished only by shape without a text label do not need a Braille label.

Controls do not depend on fine motor skills.

External reference:	WCAG 2.0/Section 508
Prior VVSG source	VVSG 1.1 - 3.3.3.f
Related requirement;	7.2-E – Touchscreen gestures 7.2-H – Accidental activation 7.2-R – Control labels visible 7.3-L – Icon labels

7.1-O – Toggle keys

The status of all locking or toggle controls or keys (such as the "shift" key) for the voting system available to the voter must be visually discernible, and also discernible through either touch or sound.

External reference:	WCAG 2.0/Section 508
Prior VVSG source:	VVSG 1.1 - 3.3.3.g

7.1-P – Identifying controls

Buttons and controls that perform different navigation or selection functions must be distinguishable by both shape and color for tactile and visual perception.

Well-known arrangements of groups of keys may be used only for their primary purpose. For example, a full alphabetic keyboard is acceptable for entering a write-in candidate name, but individual keys cannot be used for navigation or selection.

Discussion

This applies to buttons and controls implemented either on-screen or in hardware. For on-screen controls, shape includes the label on the button.

Redundant cues help those with low vision. They also help individuals who have difficulty reading the text on the screen, those who are blind but have some residual vision, and those who use the controls on a voting system because of limited dexterity. While this requirement primarily focuses on those with low vision, features such as tactile controls and on-screen controls intended primarily to address one kind of disability often assist other voters as well. The Trace Center’s EZ Access design is an example of button functions distinguishable by both shape and color: **https://trace.umd.edu/ez**

EAC RFI 2007-05 is incorporated into this requirement.

External Reference: WCAG 2.0/Section 508
EAC RFI 2007-05

Prior VVSG source: VVSG 1.1 - 3.3.2.b

7.2 – Voters and election workers can use all controls accurately, and voters have direct control of all ballot changes.

7.2-A – Display and interaction options

The voting system must provide at least the following display formats and control or navigation options to enable voters to activate their ballot, mark their ballot to vote, and verify and cast their ballot, supporting the full functionality in each mode:

1. Visual format with enhanced visual options
2. Audio format
3. Tactile controls
4. Limited dexterity controls

Discussion

Voters need to be able to choose the combination of display formats and types of controls that work for them, for example, combining the audio format with tactilely discernible controls.

Limited dexterity controls are defined in the Glossary as those that do not require dexterity and can be operated without use of hands.

Full functionality includes at least instructions and feedback:

- on initial activation of the ballot (such as insertion of a smart card), if applicable;
- on how to use accessibility features and setting;
- on a change in the display format or control options;
- for navigating the ballot;
- for contest options, including write-in candidates;
- on confirming and changing votes; and
- on final ballot submission.

External reference: WCAG 2.0/Section 508

Prior VVSG sources: VVSG 1.1 - 3.3.3.b, 3.3.8

Related requirements: 5.1-A- – Interaction modes
5.2-A – No bias

7.2-B – Navigation between contests

The electronic ballot interface must provide navigation controls that allow the voter to advance to the next contest or go back to the previous contest before completing their vote.

Discussion

For example, voters are not forced to proceed sequentially through all contests before going back to check their votes within a previous contest.

This requirement applies whether the voter is using the visual or audio format, or synchronized audio and video.

As with all requirements, this applies to all interaction modes.

External reference:	WCAG 2.0/Section 508
Prior VVSG sources:	VVSG 1.1 - 3.2.2.1.e, 3.3.3.3.e
Related requirements:	7.2-A – Display and interaction options

7.2-C – Voter control

An electronic ballot interface must give voters direct control over making or changing vote selections within a contest:

1. In a vote-for-one contest, selecting a candidate may deselect a previously selected candidate, but the system must announce the change in audio and visual display.
2. In a vote-for-N-of-M contest, the system must not deselect any candidate automatically.
3. In a vote-for-N-of-M contest, the system must inform the voter that they have attempted to make too many selections and offer an opportunity to change their selections.
4. Ballot options intended to select a group of candidates, such as straight-party voting, must provide clear feedback on the result of the action of selecting this option.
5. Ballots with preferential or ranking voting methods must not re-order candidates except in response to an explicit voter command.

Discussion

This requirement covers any selection, de-selection, or change to ballot options. It can be met in a variety of ways, including notifications or announcements of the action the system is taking. For example, if a voter attempts to mark a selection for more candidates than allowed, the system does not take an independent action to de-select a previously selected candidate, but instead notifies the voter of the problem and offers ways to correct it.

As with all requirements, this applies to all interaction modes.

This requirement addresses situations in which the voter cannot see the change take effect because the previously selected candidate is on another screen, has scrolled off the visible display area, or is out of the voter's field of vision. It is particularly important to voters using the audio format and no visual display because they often do not have a way to know that a change that occurs higher up in the contest has taken place.

Examples of feedback include visual changes on the screen and related sounds or messages in text and audio. For example, selecting a candidate is often announced visually with a check-mark image and in audio by naming the candidate selected.

If there is a visual change or announcement about the number of candidates selected (or selections still available), for example, the audio says "you have selected the maximum number of candidates in this contest" in a vote-for-N contest.

An example of feedback on the result of a complex action, such as making a selection in straight party voting, might be a message confirming the party whose candidates were selected, or even the number of candidates and contests affected by the voter's action.

Related requirements: 7.2-A – Display and interaction options
7.3-E – Feedback
7.3-F – Correcting the ballot

7.2-D – Scrolling

If the number of candidates or length of the ballot question means that the contest does not fit on a single screen using the voter's visual display preferences, the voting system must provide a way to navigate through the entire contest.

1. The voting system may display the contest by:
    - Pagination - Dividing the list of candidates or other information into "chunks," each filling one screen and providing ways for the voter to navigate among the different chunks, or
    - Scrolling – Keeping all of the content on a single long display and providing controls that allow the voter to scroll continuously through the content.
2. For either display method, the voting system interface must:
    - have a fixed header or footer that does not disappear so voters always have access to navigation elements, the name of the current contest, and the voting rules for the contest,
    - include easily perceivable cues in every interaction mode to indicate that there is more information or there are more contest options available, and

- include an option for an audio format and visual presentation that sync during scrolling.

3. The navigation method must ensure that the voting system:
    - meets all requirements for providing feedback to the voter,
    - accurately issues all warnings and alerts including notifications of undervotes and overvotes,
    - meets all requirements for control size and interaction, and keeping all controls visible,
    - does not rely only on conventional platform scroll bars, and
    - provides an opportunity to review and correct selections before leaving the contest.

Discussion

The ability to scroll through a list of candidates on a single logical page can be particularly important when a voter selects larger text or is using the audio format.

Information elements that need not scroll might include the name of the contest ("City Council Member"), the voting rules ("vote for 1") and general controls including preference settings or navigation between contests.

A scrolling interface that meets this requirement offers voters a combination of easily perceivable controls or gestures to navigate through the list of candidates or text of a ballot question. For example:

- Navigation within the contest does not rely on knowledge of any particular computer platform or interface standard.
- Navigation within the contest does not only rely on conventional platform scroll bars, which operate differently on two of the major commercial computer platforms.
- Controls have visible labels that include words or symbols.
- Controls are located in the voter's visual viewing area at the bottom (or top) of the scrolling area, for example in the center of the column of names or paragraph of text. This is especially helpful for people with low digital or reading literacy.
- Controls are identified in the audio format and can be activated in all interaction modes.

This overall requirement relates to ***7.1-G-Text size, 7.1-H-Scaling and zooming,*** and ***7.3-B-No split contests***

The controls used to meet this requirement also need to meet all other requirements including ***7.2-H – Accidental activation, 7.2.I-Touch area size, 7.2-F-Voter speech,*** and ***7.2-E-Touch gestures.***

Meeting requirements for notifications relates to ***7.3-E-Feedback***, ***7.3-F-Correcting the ballot***, ***7.3-H-Overvotes, 7.3-I-Undervotes***, and ***7.3-K-Warnings, alerts, and instructions***.

Prior VVSG source:	VVSG 1.1 - 3.2.6.a
Related requirements:	7.1-G – Text size (electronic display) 7.1-H – Scaling and zooming (electronic display) 7.3-B – No split contest 7.2-H – Accidental activation 7.2.I–Touch area size 7.2-F – Voter speech 7.2-E – Touch gestures 7.3-E – Feedback 7.3-F – Correcting the ballot 7.3-H – Overvotes 7.3-I – Undervotes 7.3-K – Warnings, alerts, and instructions
Applies to:	Electronic interfaces

7.2-E – Touchscreen gestures

Voting system devices used by voters with a touch screen may use touchscreen gestures (physical movements by the user while in contact with the screen to activate controls) in the interface if the following conditions are met:

1. Gestures are offered as another way of interacting with a touch screen and an optional alternative to the other interaction modes.
2. Gestures work consistently across the entire voting interaction.
3. Gestures do not include navigation off the current contest.
4. Gestures are used in a way that does not create accidental activation of an action through an unintended gesture.
5. Gestures are limited to simple, well-known gestures.
6. Gestures do not require sequential, timed or simultaneous actions.

Discussion

This requirement ensures that the use of gestures does not interfere with the accessibility features of the voting system or make the interface difficult to use by relying on a control mode with no easy way to make them perceivable in the visual or audio formats.

In relying on simple and common gestures, this requirement does not intend to fully duplicate the gestures for commercial mobile platforms used with an audio mode for accessibility.

Tapping (touching the screen briefly) is the most basic gesture and is used on all touch screens. Other commonly used gestures include:

- Pinching or spreading fingers to zoom
- Swiping to scroll
- Pressing and holding to drag

Examples of gestures that require sequential or simultaneous actions are double-tapping, 2, 3 or 4 finger swiping, touch and hold for a set period of time, or those that require coordinated actions with fingers on both hands. On desktop systems, assistive preference options like Sticky Keys can make these complex gestures accessible, but they require familiarity beyond what is acceptable in a voting system.

Examples of timed gestures include differentiating between long and short touches or which require touching twice in rapid succession to highlight and then activate the button or selection.

Related requirement:	7.2-H – Accidental activation 7.1-N – Tactile keys
Applies to:	Electronic interfaces

7.2-F – Voter speech

If the voting system includes speech or human sounds as a way for voters to control the system:

1. it must not require the voter to speak recognizable voting selections out loud, and
2. speech input must not be the only non-visual interaction mode.

Discussion

This requirement allows the use of speech input as long as voters can choose other ways of interacting with the voting system that do not require either vision or use of their hands.

It is also important to consider how speech would work as a way of voting in a noisy polling place environment.

External reference:	WCAG 2.0/Section 508
Prior VVSG source	VVSG 1.1 - 3.3.9.a
Related requirements:	6.1-A-Preserving privacy for voters 6.1-D-Audio privacy

7.2.G – Voter control of audio

The voting system must allow the voter to control the audio presentation including:

1. pausing and resuming the audio

2. repeating any information
3. skipping to the next or previous contest, and
4. skipping over the reading of the ballot question text.

Discussion

These features can also be useful to voters with cognitive disabilities.

This is comparable to the ability of sighted voters to:

- move on to the next contest once they have made a selection or to abstain from voting on a contest altogether, or
- skip over the wording of a referendum on which they have already made a decision prior to the voting session (for example, "Vote yes on proposition #123").

External reference:	WCAG 2.0/Section 508
Prior VVSG sources;	VVSG 1.1 - 3.3.3.b.ii, 3.3.3.b.iii, 3.3.3.b.iv, 3.3.3.b.v, 3.3.8
Applies to:	Electronic interfaces

7.2-H – Accidental activation

Both on-screen and physical controls on the voting system must be designed to prevent accidental activation.

Discussion

There are at least two kinds of accidental activation:

- When a control is activated to execute an action as it is being “explored” by the voter because the control is overly sensitive to touch.
- When a control is in a location where it can easily be activated unintentionally. For example, when a button is in the very bottom left corner of the screen where a voter might hold the unit for support.

Work on the next version of WCAG includes a similar requirement and offers guidelines for preventing accidental activation including that the activation be on the release of the control (an “up-event”) or equivalent, or that the system provides an opportunity to confirm the action.

In addition to the accessibility needs for preventing accidental activation, it can be an issue if voters perceive the voting system as changing their voting selections.

External references:	WCAG 2.0/Section 508
Prior VVSG source:	VVSG 1.1 - 3.2.6.c
Related requirements:	7.2-E – Touch gestures 7.1-N – Tactile keys

7.2-I – Touch area size

If the voting system has a touch screen, the touch target areas must:

1. be at least 12.7 mm **(**0.5 inches) in both vertical and horizontal dimensions,
2. be at least 2.54 mm (0.1 inches) away from adjacent touch areas, and
3. not overlap another touch area.

Discussion

The requirements for touch size areas on voting systems are larger than commercial standards for mobile devices:

- to ensure that the touch areas are large enough for voters with unsteady hands,
- to ensure that voting systems allow full adjustment to the most comfortable posture, and
- to allow for touchscreens that do not include advanced algorithms to detect the center point of a touch.

The required touch area size is larger than some of the commercial standards for mobile phones to allow for use by voters with limited dexterity.

The required marking area size is within sizes suggested in the draft WCAG 2.1 for target areas that accept a touch action.

An MIT Touch Lab study of **Human Fingertips to Investigate the Mechanics of Tactile Sense** found that the average human finger pad is 10-14 mm and the average fingertip is 8-10 mm.

External references:	WCAG 2.0/Section 508
Prior VVSG sources:	VVSG 1.1 - 3.2.6.c.i
Applies to:	Touch screen interfaces

7.2-J – Paper ballot target areas

On a paper ballot that a voter marks by hand, the area of the target used to mark a voting selection must be at least 3 mm (0.12 inches) across in any direction.

Discussion

This requirement applies to marking ovals, circles, squares, or other optical scan ballot designs.

Although the marking target for hand-marked paper ballots needs to be large enough to see, a target that is too large can also make it hard to fill in the area completely.

Prior VVSG source:	VVSG 1.1 - 3.2.2.2.f.i
Applies to:	Paper ballots

7.2-K – Key operability

Physical keys, controls, and other manual operations on the voting station must be operable with one hand and not require tight grasping, pinching, or twisting of the wrist. The force required to activate controls and keys must be no greater than 5 lbs. (22.2 N).

Discussion

Voters can operate controls without excessive force. This includes operations such as inserting an activation card, and inserting and removing ballots.

This does not apply to on-screen controls.

External references:	WCAG 2.0/Section 508
Prior VVSG source:	VVSG 1.1 - 3.3.4.c
Applies to:	Physical controls

7.2-L – Bodily contact

The voting station controls must not require direct bodily contact or for the body to be part of any electrical circuit. If some form of contact is required, a stylus or other device with built-in permanent tips will be supplied to activate capacitive touch screens.

Discussion

This requirement ensures that controls and touch screens can be used by individuals using prosthetic devices or that it is possible to use a stylus on touch screens for either greater accuracy or limited dexterity input.

One type of touch screen – capacitive touch panels – rely on the user's body to complete the circuit. EAC RFI 2015-05 states that they can be used if manufacturers supply a stylus or other device that activates the capacitive screen.

External references:	WCAG 2.0/Section 508
Prior VVSG source:	VVSG 1.1 - 3.3.4.d
Applies to:	Electronic interfaces

7.2-M – No repetitive activation

Voting system keys or controls must not have a repetitive effect when they are held in an active position.

Discussion

This is to preclude accidental activation. For instance, if a voter is typing in the name of a write-in candidate, depressing and holding the "e" key results in only a single "e" added to the name.

External references:	WCAG 2.0/Section 508

Prior VVSG source: VVSG 1.1 - 3.2.6.c.ii

7.2-N – System response time

The voting system's response time must meet the following standard response times:

1. The system initially responds to a voter action in no more than:
    a. 0.1 seconds for a visual change
    b. 0.5 seconds for an audio response
2. The system responds to a voter marking a vote in no more than 1 second for both a visual response and an initial audio response.
3. The system completes the visual response or display in no more than 1 second or displays an indicator that a response is still being prepared.

Discussion

This is so the voter can very quickly perceive that an action has been detected by the system and is being processed. The voter never gets the sense of dealing with an unresponsive or "dead" system. Note that this requirement applies to both auditory and visual voting system responses.

For example, if the voter touches a button to indicate a vote for a candidate, a visual system might display an "X" next to the candidate's name, and an audio system might announce, "You have voted for John Smith for Governor". Even for "large" operations such as initializing the ballot or painting a new screen, the system never takes more than 10 seconds.

In the case of audio systems, no upper limit is specified, since certain operations can take longer, depending on the length of the text being read (for example, reading out a long list of candidates running in a contest). For instance, the system might present a progress bar indicating that it is "busy" processing the voter's request. This requirement is intended to preclude the "frozen screen" effect, in which no detectible activity is taking place for several seconds. There need not be a specific "activity" icon, as long as some visual change is apparent (such as progressively "painting" a new screen or providing audio feedback).

External references: WCAG 2.0/Section 508
Prior VVSG sources; VVSG 1.1 - 3.2.6.1.a, 3.2.6.1.b, 3.2.6.1.c, 3.2.6.1.d
Applies to: Electronic interfaces

7.2-O – Inactivity alerts

If the voter has not interacted with the voting system for a long time (that is, between 2-5 minutes), the system must notify the voter and meet the following requirements:

1. Each system must specify what they mean by inactivity time and keep a record of it.

2. When the voter's inactivity time expires, the electronic ballot interface must issue an alert and provide a way for the voter to receive additional time.
3. The alert time must be between 20 and 45 seconds.
4. If the voter does not respond to the alert within the alert time, the electronic ballot interface must go into an inactive state requiring election worker intervention.

Discussion

Each type of system will have a given inactivity time that is consistent among and within all voting sessions. This ensures that all voters are treated equitably.

The timer starts when the voter finishes reading a referendum.

External references:	WCAG 2.0/Section 508
Prior VVSG sources:	VVSG 1.1 - 3.2.6.1.e, 3.2.6.1.f
Applies to:	Electronic interfaces

7.2-P – Floor space

When used according to the manufacturer's installation instructions, the voting station must allow floor space for voters using a wheelchair or a voter's assistant by:

1. providing a clear area for a wheelchair of 760 mm (30 inches) wide and 1220 mm (48 inches) deep, and
2. providing adequate room for a voter's assistant, including enough room for both the voter and an assistant to enter the area of the voting station.

Discussion

This requirement sets minimum dimensions for clear floor space around a voting station and ensures that the manufacturer's voting station design and associated installation instructions support polling place layouts that can achieve this requirement.

In planning a polling place layout, election officials should consult the U.S Access Board Technical Guide: Clear Floor or Ground Space and Turning Space (**https://www.access-board.gov/attachments/article/1553/clear%20floor%20sapce-ABA.pdf**) and the U.S. Department of Justice ADA Checklist for Polling Places (**https://www.ada.gov/votingchecklist.htm**) to be sure that a voter using a wheelchair can reach the voting station. They should also consider space needed if a voter's assistant also uses a mobility device.

External references:	WCAG 2.0/Section 508 US Access Board Clear Floor or Ground Space and Turning

	Space U.S. Department of Justice ADA Checklist for Polling Places
Prior VVSG sources:	VVSG 1.1 - 3.3.5.a, 3.3.5.b

7.2-Q – Physical dimensions

The physical dimensions of the voting station must meet the U.S. Access Board requirements in Appendix A to Part 1194 – Section 508 of the Rehabilitation Act: Application and Scoping Requirements, Chapter 4: Hardware, Section 407.8 Operable Parts: Reach Height and Depth.

Discussion

This requirement is part of Information and Communication (ICT) Standards and Guidelines, published in the Federal Register on January 8, 2017, Amended March 23, 2017 as **36 CFR Parts 1193 and 1194**.The text of the requirements for reach height and depth with illustrations can be found on the U.S. Access Board website at **https://www.access-board.gov/guidelines-and-standards/communications-and-it/about-the-ict-refresh/final-rule/text-of-the-standards-and-guidelines#407-operable-parts**

Many voting systems can be set up in a variety of ways for use in a polling place or vote center. For example, a system might sit on a table that allows voters to put their legs under the table in a polling place, but on a counter with no legroom in a vote center. Wheelchairs and scooters also allow voters different abilities to reach controls, and the voter might approach the voting system from the front or side, depending on the physical design and how it is presented to the voter.

A guide to meeting the requirements in the ADA standard for ensuring that voters can reach and use all operable parts can be found online at the Access Board website: **https://www.access-board.gov/guidelines-and-standards/buildings-and-sites/about-the-ada-standards/guide-to-the-ada-standards/chapter-3-operable-parts**

External reference:	WCAG 2.0/Section 508 U.S. Access Board Section 508 Chapter 3.407-Operable Parts
Prior VVSG sources:	VVSG 1.1 - 3.3.5.c, 3.3.5.1.a, 3.3.5.1.b, 3.3.5.1.c, 3.3.5.1.d

7.2-R – Control labels visible

Labels for controls used by voters must be placed:

1. on a surface of the voting system where voters can see them from a seated or standing posture, and
2. within the dimensions required in 7.2-Q – Physical Dimensions.

Discussion

This requirement ensures that voters can find controls, even if they are placed on a side or top surface of the voting system, and that blind voters can discover any Braille labels associated with the text label by touch.

Related requirements: 7.1-N – Tactile Keys
7.2-Q – Physical Dimensions
7.3-L – Icon labels

7.3 – Voters can understand all information as it is presented, including instructions, messages from the system, and error messages.

7.3-A – System-related errors

The voting system must help voters complete their ballots effectively, ensuring that the features of the system do not lead to voters making errors during the voting session.

Prior VVSG sources: VVSG 1.1 - 3.2.1.a, 3.2.1.b

7.3-B – No split contests

The voting system must have the capability to display a ballot so that no contest is split into two groups of options.

1. For paper ballot formats, the system must include a way of presenting a contest that does not divide the options across two columns or two pages.
2. For electronic interfaces, if a contest does not fit onto one screen view, the system must include a way to meet the requirements in 7.2-D-Scrolling for managing the way the list of options is displayed.

Discussion

There is strong evidence from recent elections that when a contest is split into two or more sections, there is a risk that the voter can perceive one contest as two (and overvote), or fail to see all of the contest options (and vote for a candidate other than the one they intend to).

This a requirement for a capability of the ballot design or election management tools for the voting system to allow election officials to lay out a ballot with good usability.

External reference: WCAG 2.0/Section 508
Prior VVSG source: VVSG 1.1 - 3.2.4.e.i
Related requirement: 7.2-D – Scrolling

7.3-C – Contest information

All ballots must clearly indicate the office or question title and the maximum number of choices allowed for each contest.

In an electronic ballot marking interface, the information for each contest includes, in a consistent order:

1. The title of the office or ballot question, including any distinguishing information such as the length of the term or the jurisdiction
2. The maximum number of selections allowed in the contest
3. In the audio format only, the number of options or candidates
4. If any selections have already been made, the number of selections remaining
5. In the audio format only, if any selections have been made, the currently selected candidates or options
6. Any instructions or reminders of how to find marking instructions, placed visually and in audio after the contest information

Discussion

This requirement is intended to work with any relevant state election laws or regulations for ballot design.

For voters using audio features, best practice is to announce how many candidates or voting options are available, providing an audio cue similar to a visual scan of the ballot in a similar way to assistive technology such as screen readers.

Placing basic instructions last helps voters using the audio format know when they can skip to making selections in the contest without missing any important information.

Prior VVSG source: VVSG 1.1 - 3.2.4.e.ii

Related requirements: 7.3-C – Maximum number of selections

7.3-D – Consistent relationship

The relationship between the name of a candidate or other voting option and the way the voter marks that selection, including the location on the ballot, must be consistent throughout the ballot including, all types of contests.

Discussion

A type of contest includes contests to:

- vote for one or more candidates,
- answer a ballot question,
- vote whether to retain a judge,
- indicate preferential ranking of candidates, or
- make a selection in other contests with distinct voting methods.

An example of how to meet this requirement is to ensure that the mechanism for marking a selection is not to the left of some candidates' names and to the right of others.

Prior VVSG source:	VVSG 1.1 - 3.2.4.e.iii
Related requirements:	7.3-N – Instructions for voters 5.2-A – No bias

7.3-E – Feedback

The voting system must provide unambiguous feedback confirming the voter's selection, such as displaying a checkmark beside the selected option or conspicuously changing its appearance.

Discussion

This requirement applies to electronic interfaces because on paper ballots the voter supplies the mark to indicate a selection, not the voting system.

This requirement also applies to the audio format. It is especially important that the way the status of the process of making selections is announced in the audio format is unambiguous. For example, the phrase "is selected" and "de-selected" can sound similar, especially at faster audio speeds. Choosing phrases that are more distinct, paying attention to the audio phrasing, and testing with the maximum audio speed can help avoid this problem.

Designers of paper ballots that include straight-party voting should test feedback features carefully to ensure that voters can understand the scope of their selection and the ballot options it affects.

Prior VVSG source:	VVSG 1.1 - 3.2.6.b
Applies to:	Electronic interfaces
Related requirements:	7.2-C – Voter Control 7.3-G – Full ballot selections review

7.3-F – Correcting the ballot

The voting system must provide the voter the opportunity to correct the ballot before it is cast and counted.

An electronic ballot interface must:

1. allow the voter to change a vote within a contest before advancing to the next contest,
2. provide the voter the opportunity to correct the ballot before it is cast or printed, and
3. allow the voter to make these corrections without assistance.

Discussion

For paper ballots, this can be achieved through appropriately placed written instructions, including requiring the voter to obtain a new paper ballot to correct a mistake.

Vote-by-mail ballots can have different instructions for making corrections from those cast in-person.

Some voting methods allow a voter to print a replacement ballot, as long as they only cast one.

Also, note the requirements for precinct-count optical scanners in ***7.3-H-Overvotes*** below.

External reference:	HAVA
Prior VVSG sources:	VVSG 1.1 - 3.2.2.c, 3.2.2.1.c, 3.2.2.1.d, 3.2.2.2.d
Related requirement:	5.2-F – Preserving votes 7.3-H – Overvotes

7.3-G – Full ballot selections review

A voting system with an electronic voting interface must provide the voter with a function to review their selections before printing or casting their ballot that:

1. displays all of the contests on the ballot with:
    - the voter's selections for that contest, or
    - a notification that they have not made a selection, or
    - a notification that they have made fewer selections than allowed, and
2. offers an opportunity to change the selections for a contest and return directly to the review screen to see the results of that change, and
3. allows the voter to continue to the function for casting the ballot without making a correction at any time in the review process.

The review function may also be provided on a scanner or other device where the voter casts a paper ballot.

Discussion

This requirement is an implementation of the HAVA requirement that voters be able to review and change their ballot before casting.

Electronic interfaces are required to prevent overvotes. This is usually done while originally marking a contest, so there are no overvoted contests to display on the review screen.

Including a review screen on a scanner that accepts ballots marked by hand gives those voters an opportunity to review how their ballot will be read by the scanner and make any corrections before casting the ballot.

External reference:	HAVA
Related requirements:	5.2-F – Preserving votes 7.3-H – Overvotes 7.3-I – Undervotes

7.3-H – Overvotes

The voting system must notify the voter if they attempt to select more than the allowable number of options within a contest (overvotes) and inform them of the effect of this action before the ballot is cast and counted.

1. An electronic ballot interface must prevent voters from selecting more than the allowable number of options for each contest.
2. A scanner or other device that a voter uses to cast a paper ballot must be capable of providing feedback both visually and in audio format to the voter that identifies specific contests for which the voter has overvoted.

Discussion

This requirement does not specify exactly how the system will respond when a voter attempts to select an "extra" candidate. For instance, the system can present the warning, or, in the case of a single-choice contest (vote for 1), simply change the vote selection and issue a warning.

For electronic ballot interfaces, this requirement does not allow disabling the features that prevent overvotes.

In the case of paper ballot systems, voters can be informed of the effect of overvoting through appropriately placed instructions.

In all cases, all requirements for accessibility apply to the notifications and warnings.

External reference:	HAVA
Prior VVSG sources:	VVSG 1.1 - 3.2.2.a, 3.2.2.1.a, 3.2.2.2.a
Related requirements:	7.2-C – Voter control 7.3-K – Warnings, alerts, and instructions
Applies to:	Electronic interfaces and ballot scanners

7.3-I – Undervotes

The voting system must notify voters in both visual and audio formats of the specific contest in which they select fewer than the allowable number of options (that is, for undervotes).

1. Both electronic interfaces and scanners must allow the voter to submit an undervoted ballot without correction.
2. The voting system may allow election officials to disable the notification of undervotes on a scanner.

Discussion

For electronic interfaces, this notification can be incorporated into the review feature.

External reference:	HAVA

Prior VVSG sources:	VVSG 1.1 - 3.2.2.b, 3.2.2.1.b
Related requirement:	7.2-C – Voter Control 7.3-K – Warnings, alerts, and instructions
Applies to:	Electronic interfaces and scanners

7.3-J – Notification of casting

If the voter successfully casts or prints the ballot, the voting system must let the voter know in both visual and audio format that they succeeded.

1. If the voter takes the appropriate action to cast a ballot, but the electronic interface does not accept and record it successfully, including failure to store the ballot image, then the interface must let the voter know and provide clear instruction as to the steps the voter will take to cast the ballot.
2. If the voter takes the appropriate action to cast a ballot, but the system does not accept and record it successfully, including failure to read the ballot or to transport it into the ballot box, the system must let the voter know.
3. A scanning device must also be capable of notifying the voter that they have submitted a paper ballot that is blank on one or both sides. The system may provide a means for an authorized election official to deactivate this capability.

Discussion

The purpose of this requirement is to provide feedback to voters to assure them that the voting session has been completed. Note that either a false notification of success or a missing confirmation of actual success violates this requirement.

Detecting situations in which the voter might be unaware that the ballot is two-sided and left one side blank is distinct from the ability to detect and warn about undervoting.

At a minimum, this requirement is intended to ensure that blind and low-vision voters receive an audio notification that a ballot is successfully cast. This might be a sound that is the audio equivalent of a waving flag or other visual.

External references:	WCAG 2.0/Section 508
Prior VVSG sources:	VVSG 1.1 - 3.2.2.d, 3.2.2.1.f, 3.2.2.2.c, 3.2.2.2.g, 3.2.2.2.a, 3.2.2.1.b

7.3-K – Warnings, alerts, and instructions

Warning, alerts, and instructions issued by the voting system must be distinguishable from other information.

1. Warnings and alerts must clearly state in plain language:

- the nature of the problem,
- whether the voter has performed or attempted an invalid operation or whether the voting system itself has malfunctioned in some way, and
- the responses available to the voter.

2. Each distinct instruction must be separated from others:
    - spatially in a visual presentation,
    - with a noticeable pause for audio formats.

Discussion

For instance, “Do you need more time? Select ‘Yes’ or ‘No’.” rather than “System detects imminent timeout condition.” In case of an equipment failure, the only action available to the voter might be to get assistance from an election worker.

Keeping instructions separate includes not "burying" several unrelated instructions in a single long paragraph.

Alerts intended to confirm visual changes to a voter using the audio format (such as confirmation that the screen has been turned on or off) can be communicated in audio, with a short text or sound.

External references:	WCAG 2.0/Section 508
Prior VVSG sources:	VVSG 1.1 - 3.2.4.c.i, 3.2.4.c.iv

7.3-L – Icon labels

When an icon is used to convey information, indicate an action, or prompt a response, it must be accompanied by a corresponding label that uses text.

The only exception is that the two 3.5 mm (1/8 inch) jacks for audio and personal assistive technology (PAT) may be labeled with tactilely discernable and visually distinct icons of a headset (for audio) and wheelchair (for the PAT connector) that are at least 13 x 13 mm in size.

Discussion

While icons can be used for emphasis when communicating with the voter, they are not to be the only means by which information is conveyed, since there is no widely accepted "iconic" language, and therefore, not all voters might understand a given icon.

External references:	WCAG 2.0/Section 508
Prior VVSG source:	VVSG 1.1 - 3.2.4.g
Related requirement:	7.1-N – Tactile keys 7.2-R – Control labels visible 8.1-E – Standard audio connectors 8.1-I – Standard PAT jacks

7.3-M – Identifying languages

When presenting a list of languages to the voter:

1. the electronic ballot interface must use the native name of each language, and
2. the controls to identify or change language must be visible on the screen, not hidden in a help or settings feature.

Discussion

The English name or spelling can also be used to identify language, along with the native name.

External reference:	VRA
Prior VVSG source:	VVSG 1.1 - 3.2.7.a.i
Applies to:	Electronic interfaces

7.3-N – Instructions for voters

The voting system must provide voters with instructions for all its operations at any time during the voting session.

1. For electronic interfaces, the voting system must provide a way for voters to get help directly from the system.
2. For paper ballots, the system must be capable of including on the ballot both text and images with instructions for how to mark the ballot.
3. Best practice is for all voting systems to present all instructions, including the verification process, near to where they are needed during the voting session.

Discussion

The purpose of this requirement is to minimize voters' need for assistance from an election worker and to permit the voter to cast and verify, privately and independently, the votes selected.

When the system works correctly, the voter will find the help they need from the system when and where they need it. For instance, only general instructions should be grouped at the beginning of the ballot; those pertaining to specific situations should be presented near those situations.

If an operation is available to the voter, it will be documented. Examples include how to make a vote selection, navigate among contests, cast a straight party vote, cast a write-in vote, adjust display and audio characteristics, or select a language.

Electronic ballot interface systems often provide assistance with a distinctive "help" button.

Instructions can be on the ballot itself or separate from the ballot, as long as the voter can find them easily.

External references:	WCAG 2.0/Section 508
Prior VVSG sources:	VVSG 1.1 - 3.2.4.a, 3.2.4.b, 3.2.4.e.iv, 7.8.6.g
Related requirement:	5.1-F – Accessibility documentation

7.3-O – Instructions for election workers

The voting system must include clear, complete, and detailed instructions and messages for setup, polling, shutdown, and how to use accessibility features.

1. The documentation required for normal voting system operation must be:
    - presented at a level appropriate for election workers who are not experts in voting system and computer technology, and
    - in a format suitable for use in the polling place.
2. The instructions and messages must enable the election workers to verify that the voting system
    - has been set up correctly (setup),
    - is in correct working order to record votes (polling), and
    - has been shut down correctly (shutdown).

Discussion

This requirement covers documentation for those aspects of system operation normally performed by election workers and other "non-expert" operators. It does not address inherently complex operations such as ballot definition. The instructions are usually in the form of a written manual, but can also be presented on other media, such as a DVD or videotape. In the context of this requirement, "message" means information delivered by the system to the election workers as they attempt to perform a setup, polling, or shutdown operation. For specific guidance on how to implement this requirement, please see: “NISTIR 7519: Style Guide for Voting System Documentation” at http://www.nist.gov/itl/vote/upload/NISTIR-7519.pdf.

For instance, the documentation should not presuppose familiarity with personal computers. And a single large reference manual that simply presents details of all possible operations would be difficult to use, unless accompanied by aids such as a simple "how-to" guide.

It is especially important that election workers and other non-expert workers know how to set up accessibility features which are not used frequently. This will help ensure voters who need these features can vote privately and independently.

Overall, election workers should not have to guess whether a system has been setup correctly. The documentation should make it clear what the system "looks like" when correctly configured.

Prior VVSG sources:	VVSG 1.1 - 3.2.8.1.c, 3.2.8.1.c.i, 3.2.8.1.c.ii, 3.2.8.1.c.iii
Related requirement:	5.1-F – Accessibility documentation

7.3-P – Plain language

Information and instructions for voters and election workers must be written clearly, following the best practices for plain language. This includes messages generated by the voting system for election workers in support of the operation, maintenance, or safety of the system.

Discussion

The plain language requirements apply to instructions that are inherent to the voting system or that are generated by default. To the extent that instructions are determined by election officials designing the ballot, they are beyond of the scope of this requirement.

Any legally required text is an exception to this plain language requirement.

Plain language best practices are guidelines for achieving clear communication and include:

- Using familiar, common words and avoiding technical or specialized words that voters are not likely to understand. For example, "There are more contests on the other side" rather than "Additional contests are presented on the reverse."
- Issuing instructions on the correct way to perform actions, rather than telling voters what not to do. For example, “Fill in the oval for your write-in vote to count” rather than, “If the oval is not marked, your write-in vote cannot be counted.”
- Addressing the voter directly rather than use passive voice when giving instructions. For example, "remove and retain this ballot stub" rather than "this ballot stub must be removed and retained by the voter."
- Stating a limiting condition first, followed by the action to be performed when an instruction is based on a condition. For example, use "In order to change your vote, do X", rather than "Do X, in order to change your vote."
- Avoiding the use of gender-based pronouns. For example, "Write in your candidate’s name directly on the ballot" rather than "Write in his name directly on the ballot."

For specific guidance on how to implement this requirement, see: “Guidelines for Writing Clear Instructions and Messages for Voters and Poll Workers” at https://www.nist.gov/sites/default/files/documents/itl/vote/032906PlainLanguageRpt.pdf .

Although part of general usability, using plain language is also expected to assist voters with cognitive disabilities.

Information written in plain language is easier to translate to meet language access requirements.

See the guidance paper on **Testing for Plain Language** for information on how this requirement might be tested using both automated evaluation programs and manual inspection.

External references:	WCAG 2.0/Section 508
Prior VVSG sources:	VVSG 1.1 - 3.2.4.c, 3.2.8.a, 3.2.4.c,ii, 3.2.4.c.iii, 3.2.4.c.v, 3.2.4.c.vi, 3.2.4.c.vii

Principle 8
Robust, Safe, Usable, and Accessible

The voting system and voting processes provide a robust, safe, usable, and accessible experience.

8.1 - The voting system's hardware, software, and accessories are robust and do not expose users to harmful conditions.

8.2 - The voting system meets currently accepted federal standards for accessibility.

8.3 - The voting system is evaluated for usability with a wide range of representative voters, including those with and without disabilities.

8.4 - The voting system is evaluated for usability with election workers.

Principle 8
ROBUST, SAFE, USABLE, AND ACCESSIBLE

The voting system and voting processes provide a robust, safe, usable, and accessible experience.

This principle covers how the voting system performs in use, including physical safety and the usability and accessibility of the complete voting system. The Guidelines under Principle 8 are:

1 - Protect from Harmful Conditions covers requirements that ensure the voting system is Robust (completing the Web Content Accessibility Guidelines' (WCAG's) organizing principles known as POUR (Perceivable, Operable, Understandable, Robust)) and does not present any harmful conditions to voters and election workers. It addresses how an electronic screen displays information the voter needs and covers personal assistive technology (PAT) and topics such as audio connectors, jacks, hearing aids, and handsets.

2 - Meet Accessibility Standards explicitly includes the entire Federal standard for accessibility, the basis for many of the requirements in Principle 7 for voting system electronic interfaces. This standard can fill in any gaps the VVSG 2.0 does not specifically address. This is especially important for the part of the voting system that might use general interfaces, such as a browser-based ballot marking system that runs on personal computers.

3 and 4 - Usability Tests require usability testing the voting system to ensure that it not only meets the detailed design requirements but will function well for both voters and election workers in use. Testing with a variety of voters, including those with and without disabilities, ensures the voting system is usable and assessible to all voters. The testing with election workers ensures that he system's setup, polling, and shutdown are relatively easy to learn, understand, and perform.

Principle 8 is related to Guideline 2.2, which requires a user-centered design and development process for the entire voting system. It covers election workers and a wide range of representative voters, including those with and without disabilities.

8.1 – The voting system's hardware, software, and accessories are robust and do not expose users to harmful conditions.

8.1-A – Electronic display screens

If the voting system uses an electronic display screen, the display must have the following characteristics:

1. For all electronic display screens:
    - Antiglare screen surface that shows no distinct virtual image of a light source or a means of physically shielding the display from such reflections
    - Minimum uniform diffuse ambient contrast ratio for 500 lx illuminance: 10:1

2. If the display is the primary visual interface for making vote selections:
    - Minimum diagonal display size: 12 inches
    - Minimum display resolution: 1920 x 1080 pixels

3. If the display screen is for messages to voters or poll workers:
    - Minimum diagonal display size: 9.5 inches
    - Minimum display resolution: 1280x800 pixels

Discussion

Displays that measure larger than the 12 inch diagonal provide the opportunity for ballot layouts that can more easily use large text settings.

Prior VVSG sources:	VVSG 1.1 - 3.2.5.a, 3.2.5.a.ii, 3.2.5.a.iii, 3.2.5.a.iv, 3.2.5.a.v, 3.2.5.a.vi, 3.2.5.a.vii
Applies to:	Electronic interfaces

8.1-B – Flashing

If the voting system emits lights in flashes, there must be no more than three flashes in any one-second period.

Discussion

This requirement has been updated to meet WCAG 2.0 and Section 508 software design issue standards, see:

- WCAG 2.0 requirements for flickering and flashing
- Section 508 requirements for flicker and flash

External references:	WCAG 2.0/Section 508

Prior VVSG sources: VVSG 1.1 - 3.2.5.a.i
Applies to: Electronic interfaces

8.1-C – Personal Assistive Technology (PAT)

The support provided to voters with disabilities must be intrinsic to the voting system. This means a voter's personal assistive devices will not be necessary to operate the voting system correctly. This does not apply to personal assistive technology required to comply with 5.1-A.

Discussion

This requirement does not preclude the voting system from providing interfaces to assistive technology. (See definition of "personal assistive devices" in the Glossary). Its purpose is to ensure that voters are not required to bring special devices with them in order to vote successfully.

This requirement assumes that voters will have with them any personal headsets, hearing aids, eyeglasses, canes, or other assistive devices they customarily use.

See the **White Paper: Assistive Technology in the Polling Place: Current and emerging technology**, Dec. 28, 2016

External references: WCAG 2.0/Section 508
Prior VVSG source: VVSG 1.1 - 3.3.1.c

8.1-D – Secondary ID and biometrics

If a voting system uses biometric measures for identifying or authenticating voters and election workers, it must provide an alternative that does not depend on the same biometric capabilities.

Discussion

For example, if fingerprints are used for voter identification, another mechanism will be provided for voters without usable fingerprints.

External references: WCAG 2.0/Section 508
Prior VVSG source: VVSG 1.1 - 3.3.1.d

8.1-E – Standard audio connectors

The voting system must provide its audio signal for the audio format interface through an industry standard connector using a 3.5 mm (1/8 inch) stereo headphone jack to allow voters to use their own audio assistive devices for private listening.

External references: WCAG 2.0/Section 508
Prior VVSG source: VVSG 1.1 - 3.3.3.c.i
Applies to: Electronic interfaces

8.1-F – Discernable audio jacks

The audio jack on any voting station device must be in a location that voters can easily discover, discernable by touch while sitting or standing in front of the unit, and not located near a sharp edge.

Discussion

For example, if the jack is slightly recessed with a round bezel, it will be easier for voters to identify the jack and to insert the headset plug into it.

8.1-G – Telephone style handset

If the voting system uses a telephone style handset or headphone to provide audio information, it must provide a wireless T-Coil 9 coupling for assistive hearing devices so it provides access to that information for voters with partial hearing, achieving at least a category T4 rating as defined by the American National Standard Institute (ANSI) for Methods of Measurement of Compatibility between Wireless Communications Devices and Hearing Aids, ANSI C63.19 [ANSI11].

External references: WCAG 2.0/Section 508
ANSI C63.19
Prior VVSG source: VVSG 1.1 - 3.3.3.c.ii
Related requirement: 8.1-J – Hearing aids
6.1.2 – Audio privacy

8.1-H – Sanitized headphones

A sanitized headphone or handset must be made available to each voter.

Discussion

This requirement can be achieved in various ways, including the use of "throwaway" headphones or sanitary coverings.

Prior VVSG source: VVSG 1.1 - 3.3.3.c.iii

8.1-I – Standard PAT jacks

A vote capture device or other voting station device must provide a 3.5 mm (1/8 inch) industry standard jack voters can use to connect their personal assistive technology switch to the system.

1. This jack must allow only switch data to be transmitted to the system.
2. The system must accept switch input that is functionally equivalent to other input methods.
3. All the functionality of the voting system must be available through technology using this input mechanism.

Discussion

This requirement ensures that the voting systems are operable by voters with limited dexterity who do not have the use of their hands. Examples of personal assistive technology switches include dual switches and "sip and puff" devices.

Ideally, the jack will be on the tactile keypad or have some other mechanism to provide sufficient reach to a wheelchair tray or the voter's lap.

While it is desirable that the voter be able to independently initiate use of the non-manual input mechanism, this requirement guarantees only that the voter can vote independently once the mechanism is enabled.

External references:	WCAG 2.0/Section 508
Prior VVSG source:	VVSG 1.1 - 3.3.4.a

8.1-J – Hearing aids

Voters who use assistive hearing devices must be able to use voting devices as intended:

1. The voting device must not cause electromagnetic interference with assistive hearing devices that would substantially degrade the performance of those devices.
2. The voting device, measured as if it were a wireless device, must achieve at least a category T4 rating as defined by American National Standard [ANSI11] for Methods of Measurement of Compatibility between Wireless Communications Devices and Hearing Aids, ANSI C63.19 [ANSI11].

Discussion

"Hearing devices" include hearing aids and cochlear implants.

External references:	WCAG 2.0/Section 508 ANSI C63.19
Prior VVSG source:	VVSG 1.1 - 3.3.6.c

Related requirement: 8.1-G – Telephone style handset

8.1-K – Eliminating hazards

Devices associated with the voting system must be certified in accordance with the requirements of UL 60950-1 [UL07], Information Technology Equipment – Safety – Part 1 by a certification organization accredited by the Department of Labor, Occupational Safety and Health Administration's Nationally Recognized Testing Laboratory program.

The certification organization's scope of accreditation is acceptable if it includes IEC/UL 60950-1 [UL07].

Discussion

IEC/UL 60950 is a comprehensive standard for IT equipment and addresses all the hazards discussed above under Safety.

External references: IEC/UL 60950-1

Prior VVSG sources: VVSG 1.1 - 3.2.8.2.a, 3.2.8.2.b

8.2 – The voting system meets currently accepted federal standards for accessibility.

8.2-A – Federal standards for accessibility

Voting systems must meet federal standards for accessibility, including the current version of Section 508 of the Rehabilitation Act, in effect as of January 18, 2018, and the WCAG 2.0 Level AA checkpoints included in that standard.

Discussion

The Section 508 Standards apply to electronic and information technology, including computer hardware and software, websites, multimedia, and other technology such as video, phone systems, and copiers. The final rule was published in the **Federal Register** on January 18, 2017 as 36 CFR Parts 1193 and 1194 (RIN 3014-AA37) and can be found on the Access Board website: **https://www.access-board.gov/guidelines-and-standards/communications-and-it/about-the-ict-refresh/final-rule**

External references:	WCAG 2.0/Section 508 and ADA
Applies to:	Electronic interfaces

Suggested edit 8.3 – The voting system is evaluated for usability with a wide range of representative voters, including those with and without disabilities.

8.3 – The voting system is evaluated with a wide range of representative voters, including those with and without disabilities, for effectiveness, efficiency, and satisfaction.

8.3-A – Usability tests with voters

The manufacturer must conduct usability tests on the voting system, including all voter activities in a voter session from ballot activation to verification and casting.

1. The test participants must include voters who represent the following:
    - General population, using the visual interface
    - Voters who speak all supported languages as their primary language
    - Blind voters, using the audio format plus tactile controls
    - Voters with low vision, using the enhanced visual features with or without audio
    - Voters with limited dexterity, using the visual-tactile interface
2. The manufacturer must submit a report of the results of their usability tests, including effectiveness, efficiency, and satisfaction measures, as part of the Technical Data Package (TDP) using the version of the Common Industry Format modified for voting systems (CIF-for-Voting Systems).

Discussion

Voting system developers are required to conduct realistic usability tests on their product before submitting the system to conformance testing. This is to ensure that the user-centered design process required for quality implementation has produced a usable and accessible voting system.

Prior VVSG sources;	VVSG 1.1 - 3.3.3.a, 3.3.3.a.i, 3.3.10.a-c, 3.2.7.a.iv
Related requirements:	5.1-D – Accessibility features 2.2-A – User-centered design process

Suggested edit 8.4 – The voting system is evaluated for usability with election workers.

8.4 – The voting system is evaluated for usability by election workers.

8.4-A – Usability tests with election workers

The manufacturer must conduct usability tests of the voting system setup, polling, and shutdown as documented by the manufacturer, with representative election workers, to demonstrate that election workers can learn, understand, and perform these tasks successfully.

1. The tasks to be covered in the test must include:
    - Setup and opening for voting
    - Operation during voting
    - Use of assistive technology or language options that are part of the voting system
    - Shutdown at the end of a voting day during a multi-day early voting period, if supported by the voting system
    - Shutdown at the end of voting including running any reports
    - Providing ballots in different languages
    - Selecting the correct ballot type (for example, for vote centers)
    - Setting up the voting system to use different interaction modes
2. The test participants must include typical election workers representing a range of experience.
3. The manufacturer must submit a report of the results of their usability tests, as part of the Technical Data Package (TDP) using the Common Industry Format modified for voting systems (CIF-for-Voting Systems).

Discussion

This requirement covers procedures and operations for those aspects of system operation normally performed by election workers and other "non-expert" operators. It does not address inherently complex operations such as ballot definition or system repair. These "normal" procedures should not require any special expertise. The procedures may require a reasonable amount of training, similar to the training generally provided for temporary election workers.

Prior VVSG sources:	VVSG 1.1 - 3.2.8.1.a, 3.2.8.1.b, 3.2.8.1.b.i
Related requirement:	7.3-N – Instructions for election workers 2.2-A – User-centered design process

Principle 9
Auditable

The voting system is auditable and enables evidence-based elections.

9.1 - An error or fault in the voting system software or hardware cannot cause an undetectable change in election results.

9.2 - The voting system produces readily available records that provide the ability to check whether the election outcome is correct and, to the extent possible, identify the root cause of any irregularities.

9.3 - Voting system records are resilient in the presence of intentional forms of tampering and accidental errors.

9.4 - The voting system supports efficient audits.

Principle 9
AUDITABLE

The voting system is auditable and enables evidence-based elections.

The requirements for Principle 9 include ensuring that an error in the voting system cannot cause an undetectable change in the election results, that the system produces records that are resilient and can be checked, and produces records that enable an efficient compliance audit. **The sections in Guideline 9.1 cover**:

1 - Software independence requires that the voting system provide proof that the ballots have been recorded correctly and are compliant within the Paper-based System Architecture or Cryptographic E2E System Architectures. In addition, the manufacturer documents the mechanism used to provide software independence.

2 – Tamper-evident records are needed to enable detection of incorrect election outcomes. They need to capture the voter's ballot selection when each ballot is cast.

3 - Voter verification records need to allow voters the opportunity to verify that the system correctly interpreted their ballot selections and that they can identify errors and restart a voting session if a ballot is unacceptable.

4 – Auditable means the voting system generates records that enable external auditors to verify that ballots are correctly tabulated, even if the system is compromised or there are faults in components. The manufacturer is to provide a procedure to verify that cast records are correctly tabulated.

5 - Paper records covers the requirement that the voting system produce a verifiable paper record of the voter's ballot selection and retain a copy of that selection which has a unique identifier. The voter needs to be able to understand the recorded ballot selection and it needs to agree with the selections made by the voter.

6 - E2E cryptography deals with the protocol used in the voting system, requiring that it be publicly available for review for 2 years before it enters the voting system. Individuals will get a receipt and be able to confirm that the system correctly interpreted their ballot selections. Voters will also be able to verify that their ballots are included in the tabulation results.

7 - Audit support deals with the requirement that the system manufacturer documents the procedure to determine the number of ballots to be checked to reach an election-official-specified margin of error for a given contest, including the possible use of random numbers.

In 9.2 – Audit procedures deals with the need to produce readily available records so the election outcomes can be checked for correctness, and also help identify the cause of any

irregularities. Problems need to be identified in a post-election audit both during the audit and when completed. The voting systems needs to count and report the number of ballots cast.

In 9.3 - Resilient records covers the data protection requirements necessary to ensure that voting system records are resilient in the presence of both intentional forms of tampering and accidental errors.

In 9.4 - Efficient audit describes the system that will produce the records that assist election officials in conducting compliance audits.

9.1 - An error or fault in the voting system software or hardware cannot cause an undetectable change in election results.

9.1.1 – Software independence

9.1.1-A – Software independent

The voting system must be software independent.

Discussion

Software independence means that an undetected error or fault in the voting system's software is not capable of causing an undetectable change in election results. All voting systems need to be software independent in order to conform to the VVSG.

There are two essential concepts behind applying software independence:

- it is be possible to audit voting systems to verify that ballots are being recorded correctly, and
- testing software is so difficult that audits of voting system correctness cannot rely on the software itself being correct.

Therefore, voting systems need to be 'software independent' so that the audits do not have to trust that the voting system's software is correct. The voting system will provide proof that the ballots have been recorded correctly, that is, voting records will be produced in ways in which their accuracy does not rely on the correctness of the voting system's software.

This is a major change from previous versions of the VVSG, because previous versions permitted voting systems that are software dependent, that is, voting systems whose audits rely on the correctness of the software. One example of a software dependent voting system is the DRE, which is now non-conformant to this version of the VVSG.

There are currently two methods specified in the VVSG for achieving independence:

- through the use of independent voter-verifiable paper records, and
- E2E cryptographic voting systems.

Prior VVSG source: VVSG 2007 - 2.7-A

9.1.1-B – Paper-based or cryptographic E2E system

Voting systems must meet the requirements within the Paper-based System Architectures or Cryptographic E2E System Architectures section, or both.

Discussion

Both of these architectures are software independent, but they can both be used within the same voting system. In this case, the system would need to be compliant with both sets of requirements.

9.1.1-C –Mechanism documentation

A voting system manufacturer must document the mechanism used to provide software independence.

Discussion

Without knowing the specific mechanism, it is difficult to determine if the system truly is software independent.

This documentation should explain how any changes to the election outcome are detectable regardless of any fault or error in the voting system software. This may include how the voting systems handles a ballot after it is cast by the voter. For example, this documentation may answer the following questions:

- Is it able to print on the ballot?
- What information is printed on the ballot?
- Where is that information printed?

9.1.2 – Tamper evidence

9.1.2-A – Tamper evident records

The voting system must produce tamper-evident records that enable detection of incorrect election outcomes, including:

1. capturing the contents of each vote at the time of each ballot's casting, and
2. recording detected errors in a tamper-evident manner.

Discussion

Tamper-evident records include paper ballots and artifacts from an E2E voting system.

The record also ensures that identified issues and other problems cannot be lost or unintentionally modified once they are discovered.

Applies to: Voting Device

9.1.2-B – Tamper-evident record creation

A tamper-evident record of the voter's ballot selections must be captured when each ballot is cast.

Discussion

Precinct-based voting systems are the only way to meet this requirement. Entirely separate voting channels, such as remote vote-by-mail, do not offer this opportunity to the voter.

Applies to: Precinct-based voting systems

9.1.3 – Voter verification

9.1.3-A – Records for voter verification

The voting system must provide individual voters the opportunity to verify that the voting system correctly interpreted their ballot selections.

Discussion

Precinct-based voting systems are the only way to meet this requirement. Entirely separate voting channels, such as remote postal voting, do not offer this opportunity to the voter.

Applies to: Vote Capture Devices

9.1.3-B – Identification of errors

The voting system must offer voters the opportunity to identify ballot errors before it is cast.

Applies to: Paper-based system architectures
Cryptographic E2E system architectures

9.1.3-C – Ballot error correction

The voting system must allow a voter to restart a voting session if a ballot is deemed unacceptable.

Applies to: Paper-based system architectures

9.1.3-D – Voter reported errors

Voting system documentation must describe a method, either through procedural or technical means, for voters to report detected errors or incorrect results.

Discussion

This can include a voter alerting an election worker or pressing a button on the machine to report detected errors or incorrect results.

9.1.4 – Auditable

9.1.4-A – Auditor verification

Voting systems must generate records that would enable external auditors to verify that cast ballots were correctly tabulated.

Discussion

The voting systems themselves cannot make records available to the public. The manner and decision to make these records available is made by a state and or local jurisdiction. This requirement only ensures that the records themselves are generated and can be easily accessed without additional software or assistance from the voting system manufacturer. This requirement is meant to enable external auditors to perform their own count of the election results.

Applies to:	Voting Device
Related Requirements:	Principle 1 – High Quality Design

9.1.4-B – Auditable with compromised software, firmware, or hardware

The voting system must enable a meaningful audit in the presence of:

1. compromised or malicious software resident on the system
2. compromised or malicious hardware components
3. faults or errors in software components
4. faults or errors in hardware components

Discussion

The production of tamper evidence records protects against this scenario.

9.1.4-C – Documented procedure

The voting system manufacturer must provide a documented procedure to verify that cast ballots were correctly tabulated.

Discussion

This documentation includes procedures and technical practices that verify the results post-election.

9.1.5 – Paper records

9.1.5-A – Paper record production

The voting system must produce an independently verifiable paper record of the voter's ballot selections.

Discussion

Voting systems that use independent voter-verifiable records can satisfy the software independence requirement and achieve conformance to the VVSG.

Applies to: Paper-based system architectures

9.1.5-B – Paper record retention

The voting system must retain a paper record of the voter's ballot selections.

Applies to: Paper-based system architectures

9.1.5-C – Paper record intelligibility

The recorded ballot selections must be presented in a human-readable format understandable by the voter.

Discussion

The requirement ensures that a human-readable version of the data is printed whenever a barcode is used to encode ballot selections.

Applies to: Paper-based system architectures

9.1.5-D – Matching selections

All representations of a voter's ballot selections produced by the voting system must agree with the selections made by the voter.

Applies to: Paper-based system architectures

9.1.5-E – Paper record transparency and interoperability

All representations of a voter's ballot selections must use an open and interoperable format.

Applies to: Paper-based system architectures

9.1.5-F – Unique identifier

Each paper ballot that is counted may contain a unique identifier, which can be printed on the ballot.

Discussion

Voting systems are not required to add a unique identifier to ballots, but all voting systems that are certified with risk-limiting audit (RLA) capabilities need to be able to affix a ballot identifier.

Applies to: Paper-based system architectures

Related requirements: 9.4-B – Efficient risk limiting audit
9.1.1-C –Mechanism documentation

9.1.5-G –Preserving software independence

After a voter casts their ballot, the voting system must not physically be able to print in the area where the voter's ballot selections reside.

Discussion

After a voter casts their ballot, a voting system may print on paper ballot to apply a unique identifier that is later used for auditing purposes. To preserve software independence the voting system should not be able to print over or within the ballot selection area because that would cause an undetectable change to the election outcome. Instead the voting system should only be able to print outside of the bounds of the ballot selection area and may also create further distinction by printing in a different font style or color.

This printing process should be preserved regardless of software or hardware updates.

Related requirements: 9.1.1-C Mechanism Documentation

9.1.6 – E2E Cryptography

9.1.6-A – Cryptographic E2E transparency

The cryptographic E2E protocol used in the voting system must be publicly available, without an explicit request, for open review for 2 years before it enters the voting system certification process.

Applies to: Cryptographic E2E system architectures

9.1.6-A.1– Verified Cryptographic Protocol

The E2E cryptographic protocol used by the voting system must be evaluated and approved through a public process established by the EAC.

Discussion

Due to the lack of E2E verifiable voting systems available within the current market, there are no verified E2E cryptographic protocols. A standard public process for approval of the E2E cryptographic protocols will need to be established outside of the VVSG. Once this process is established, the VVSG requirements can point to the approved/verified cryptographic protocols as acceptable for use within an E2E verifiable voting system.

9.1.6-A.2 – Public availability of E2E cryptographic protocol implementation

The implementation of the E2E cryptographic protocol as used in the voting system must be publicly available, without an explicit request, for open review upon the system being submitted for certification.

Discussion

Lessons learned from the analysis of the source code of the Swiss Post system shows the value in making this code available for public review.

See Lewis, Sarah Jamie, Olivier Pereira, and Vanessa Teague. "How not to prove your election outcome." (2019). and Lewis, Sarah Jamie, Olivier Pereira, and Vanessa Teague. "Ceci n'est pas une preuve." (2019).

Applies to: Cryptographic E2E system architectures

9.1.6-B – Cryptographic ballot selection verification by voter

The voting system must…

1. be capable of providing evidence that an individual voter can use to confirm that the voting system correctly interpreted their ballot selections, while in the polling place.
2. provide evidence such that if there is an error or flaw in the interpretation of the voters' selections, the evidence can be used for detection of the error or flaw.

Discussion

This requirement addresses cast-as-intended verification.

Interpretation is the process by which the voting system converts the voter's contest option selections into the format used to store these selections. Therefore, this evidence must sufficiently

prove the representation of the voter's contest option selections in digital form matches the voter selections as provided to the system.

Giving voters the opportunity to verify the voting system stored their ballot choices correctly is a fundamental building block in an end-to-end verifiable voting system.

See Benaloh, Josh, Ronald Rivest, Peter Y. A. Ryan, Vanessa Teague, and Poorvi Vora. "End-to-end verifiability." (2014) and Kulyk, Oksana, and Melanie Volkamer. "Usability is not Enough: Lessons Learned from 'Human Factors in Security' Research for Verifiability." *E-Vote-ID 2018* (2018): 66 for more information on the various implementations of this technique.

Applies to:	Cryptographic E2E system architectures
Related Requirements:	Principle 10 - Ballot Secrecy 6.2-A – Voter Independence Principle 7 - Marked, Verified, and Cast as Intended

9.1.6-B.1 – Methods for cryptographic ballot selection verification

The voting system documentation must include…

1. the method for the voter to use the evidence provided for ballot selection verification to verify the correct interpretation of their ballot
2. a list of known verification tools, their supplier, and how the verification tools are used

Discussion

Voter intent verification often relies on external verification tools to assist voters in the verification step(s). These can be external verifiers, which is either a second device, a website of a trusted institution, or software running inside the polling location. The manufacturer must provide documentation explaining the verification options available to voters. If the jurisdiction is expected to provide the verification tool or service, this must also be documented.

Applies to:	Cryptographic E2E system architectures
Related Requirements:	9.1.6-B – Cryptographic ballot selection verification by vote

9.1.6-C – Ballot receipt

The voting system must provide a voter with a receipt that allows them to verify that their ballot has been correctly recorded and tallied by the system. These receipts…

1. do not display any ballot selections made by the voter

2. do not enable the voter to prove their selections on the cast ballot to others
3. are represented in an open and interoperable format
4. may contain a unique identifier
5. are accessible, verifiable, and preserve voter-privacy

Discussion

This evidence should fail to confirm a voter's ballot has been correctly recorded and tallied by the system if the ballot has been removed, tampered with, or its selections altered, added to, or removed.

The ballot receipts should…

- be accessible
- be verifiable
- preserve voter-privacy
- ensure that voters can mark, verify, and cast their ballot in an accessible and verifiable manner.

Applies to:	Cryptographic E2E system architectures
Related Requirements:	Principle 10 - Ballot Secrecy Principle 4 – Interoperable 6.2-A – Voter Independence Principle 7 - Marked, Verified, and Cast as Intended

9.1.6-D – Evidence export

The voting system must…

1. be capable of exporting all evidence supporting ballot tabulation verification.
2. provide the export in an open and consumable format.

Discussion

Most recorded-as-cast verification approaches require the public posting of the evidence at some point after all ballots have been aggregated and tallied. As required in the previous requirement, the evidence must not reveal how voters voted. The public posting does not have to be provided by the voting system, but the voting system must provide the evidence such that it can be published, and the verification process made accessible to voters.

Applies to:	Cryptographic E2E system architectures

Related Requirements: Principle 4 - Interoperable

9.1.6-E– Mandatory ballot availability

The voting system must make available all encoded ballots for public posting.

Applies to: Cryptographic E2E system architectures

9.1.6-F – Verification of encoded votes documentation

The voting system documentation must include…

1. the expected method by which voters will perform the ballot tabulation verification.
2. How this method provides voters with the opportunity to verify that their ballots are included within the tabulation results.

Discussion

For example, a common method is to publish tokens to a public bulletin board. The manufacturer should document this method or its alternative. The bulletin board, itself, might not be included in the scope of the voting system but the voting system must provide an export of the tokens/evidence to be published on the bulletin board.

Applies to: Cryptographic E2E system architectures

9.1.6-G – Verifier reference implementation

The voting system documentation must include…

1. a free publicly available reference implementation of a tool which can be used:
    a. to verify evidence provided to a voter to prove that their ballot choices were correctly interpreted
    b. to verify the evidence reported for voters to perform ballot tabulation verification
2. a free publicly available reference implementation of a tool which can be used to verify evidence provided to a voter to prove that their ballot choices were correctly interpreted
3. The build instructions for the reference implementation, along with the tool,
4. licensing to allow for examination, modification, recompilation, and distribution.

Discussion

For the system to support the cast-as-intended property of end-to-end verifiable systems there must be at least one tool available to voters to verify that their ballot selections have been correctly interpreted. Additionally, for a cryptographic E2E system be software independent, the voters need to have choices about what software use and trust when performing verification. By providing an open source reference implementation, voters will have more choices when selecting a tool to verify their ballot selections.

Applies to:	Cryptographic E2E system architectures
Related Requirements:	9.1.6-B – Cryptographic ballot selection verification by voter

9.1.6-H– Privacy preserving, universally verifiable ballot tabulation

The voting system tabulation process must preserve the privacy of every voter and provide a method for public verification.

Discussion

To be publicly verifiable, the approach provides a means for any auditor or observer to verify the correct decryption and tabulation of the votes (not necessarily in that order) using cryptographic proofs that are generated by the process.

9.1.7 – Audit support

9.1.7-A – Number of ballots to check

A voting system manufacturer must document the procedure to determine the number of ballots which need to be checked to reach an election-official-specified margin of error for a given contest.

Discussion

To ensure that the election outcome is correct within a specified margin of error, a minimum number of ballots will be checked. This can be performing with paper records in paper-based system architectures which are checked by election officials or checks by voters in cryptographic E2E system architectures. This is important to understanding how efficient the system is at detecting changes due to an error or fault.

9.1.7-B – No fixed margin of error

The voting system must allow election officials to determine the margin of error used to determine the number of ballots to check.

Discussion

This requires the documentation of the margins to be specified as an equation rather than having specific margins built into the system. Additional inputs such as margin of victory, total number of voters, number of voters for each candidate, actual ballots, or an audit trail, may be needed to determine the number of ballots needed.

9.1.7-C – Random number usage

If a voting system generates random or pseudo-random numbers, the manufacturer must document the method used to obtain the numbers and how the random numbers are used within the voting system.

Discussion

Various systems used to implement software independence require random numbers, whether for ballot selection for audits or cryptographic purposes.

This documentation should specify…

- how random numbers are generated
- what any random numbers are used for

The method for generating the random numbers should meet the requirement 10.2.2-F *Random number generation.*

Related requirements:	10.2.2-F Random number generation
External reference	NIST SP 800-90A Rev 1

9.2 - The voting system produces readily available records that provide the ability to check whether the election outcome is correct and, to the extent possible, identify the root cause of any irregularities.

9.2-A – Compliance audit procedures

The voting system documentation must specify the election procedures necessary to perform a compliance audit.

Discussion

A compliance audit ensures that the election audit trail is sufficiently accurate to reconstruct the outcome according to how voters cast their ballots. Compliance audits provide assurance that a full hand count of the election audit trail shows the outcome according to how the voters really voted.

External references: Evidence-Based Elections by P.B. Stark and D.A. Wagner
Related requirements: 3.1.3-D – Audit Procedures

9.2-B – General post-election audit procedures

The voting system documentation must specify the election procedures necessary to perform a post-election audit.

9.2-C – Generating CVRs

The voting system must be capable of recording and reporting a cast vote record for each ballot.

9.2-D – Reporting intermediate results

The voting system must be able to report intermediate results as the audit is being conducted.

9.2-E – Reporting unusual audit events

The voting system must be capable of reporting problems as they arise (for example, matching failures).

9.2-F – Reporting format

The voting system manufacturer must document the intermediate and final election audit results in an open format.

9.2-G – Ballot count

Voting systems must count and report the number of ballots cast.

Discussion

This needs to be granular enough to have voting devices and tabulators count and report the number of ballots cast.

9.3 - Voting system records are resilient in the presence of intentional forms of tampering and accidental errors.

9.3-A – Data protection requirements for audit records

All voting systems must meet the requirements listed under Principles 13.1 and 13.2

Related requirements 13.1 and 13.2

9.4 - The voting system supports efficient audits.

9.4-A – Efficient compliance audit

The voting system must produce records to enable an efficient compliance audit.

Discussion

Voting systems need to provide information that will assist election officials in conducting compliance audits, whenever possible. While compliance audits check that procedures are followed, voting systems can provide information that aids in conducting this audit. For example, inspection of event logs is much more efficient if the logs are available in human readable text format. Using event codes in logs, which requires manual decoding, is an example of a record which impairs the efficiency of compliance audits.

9.4-B – Efficient risk-limiting audit

A voting system must produce paper records that allow election officials to conduct an efficient risk-limiting audit.

Discussion

Voting systems contain information which enables election officials to conduct efficient risk limiting audits. For example, batch subtotal reporting by the voting system, may make the process of ballot sampling more efficient.

9.4-C – Unique ballot identifiers

The voting system must enable election auditors to uniquely address individual ballots.

Discussion

This capability is needed to support RLAs.

Applies to: Auditing system

9.4-D – Multipage ballots

The voting system must be able to appropriately manage multipage ballots during an audit.

Applies to: Auditing system

Principle 10
Ballot Secrecy

The voting system protects the secrecy of voters' ballot selections.

10.1 - Ballot secrecy is maintained throughout the voting process.

10.2 - The voting system does not contain nor produce records, notifications, information about the voter or other election artifacts that can be used to associate the voter's identity with the voter's intent, choices, or selections.

Principle 10
Ballot Secrecy

The voting system protects the secrecy of voters' ballot selections.

The requirements for Principle 10 include ensuring ballot secrecy and ensuring that nothing is produced that would associate the voter's identity with their votes. A related topic, Principle 6: Voter Privacy, covers voter privacy during voting.

10.1 - Use of voter information covers the requirement that ballot secrecy is maintained throughout the voting process.

10.2 - No association of the voter's choices with the voter's identity. The sections in Guideline 10.2 cover:

1 – Voter associations requires that there be no direct or indirect association between the voter's identity and their ballot, with the exception of certain instances when used in end-to-end (E2E) voting systems. It covers how election workers can select the indirect association option and how these ballots are to be stored separately from cast ballots. It also requires encryption of ballots not cast that contain an indirect association.

2 – Identification in vote records covers the use of identifiers for tying CVRs and ballot images to paper ballots and the need for them to be distinct from identifiers used for indirect associations. The voting system cannot allow for any information that could be used to determine the order in which votes are cast or include any information identifying a voter. Aggregate and final totals also will not allow identification of a voter.

3 – Access to cast vote records covers the need to limit information about and access to the storage location for CVRs, ballot images and ballot selections. Any such access needs to be authorized and logged in.

4 – Voter information in other devices and artifacts explains that receipts produced by a voting system cannot contain voter information. At the same time, the voting system needs to ensure ballot secrecy for any receipts it does issue. No part of the audit trail can contain individual or aggregate selections and nor can activation devices create or retain information that can be used to identify a voter's ballot.

10.1 - Ballot secrecy is maintained throughout the voting process.

10.1-A – System use of voter information

The voting system must be incapable of accepting, processing, storing, and reporting identifying information about a specific voter, with the exception of blank ballot distribution and online ballot marking systems.

Discussion

Examples include first name, last name, address, driver's license, and voter registration number. The voting system cannot prevent a voter from self-identifying within write-in fields.

10.2 - The voting system does not contain nor produce records, notifications, information about the voter, or other election artifacts that can be used to associate the voter's identity with the voter's intent, choices, or selections.

10.2.1 – Voter associations

10.2.1-A – Direct voter associations

The voting system must not create or store direct associations between a voter's identity and their ballot.

Discussion

A direct voter association would be the voting system storing that John Smith voted for George Washington. Other examples of a direct association would include tying ballot selections to a social security number, voter identification number, or driver's license number. (This is not an exhaustive list of direct voter association examples.)

10.2.1-B – Indirect voter associations

Only paperless systems may use indirect associations; other systems must not.

Discussion

Certain channels of voting require indirect associations so that ballots can be removed before the ballot is read and counted. Some reasons include signature mismatch or death of a voter. Once a ballot is read and counted, the ballot is permanently stripped of its identifier. The most common example of indirect association would be a randomly generated number. Ballots with indirect associations are not considered read or counted until the association is removed.

This requirement only applies to paperless voting systems that also meet the requirements under guideline 9.1, which state that the voting system must be software independent. During the writing of these requirements, cryptographic E2E verifiable voting systems are a potential paperless and software independent system that could be applicable for this requirement.

Applies to: E2E voting system architectures

10.2.1-C – Use of indirect voter associations

The voting system must only use indirect associations for situations when a voter needs to fill out a ballot before their eligibility is determined.

Discussion

Certain channels of voting require indirect associations so that ballots can be removed before casting for a variety of reasons including signature mismatch or death of a voter. The act of casting the ballot permanently strips it of an identifier.

The most common example of indirect association would be a randomly generated number. Ballots with indirect associations are not considered cast until the association is removed.
Best practice would ensure that indirect voter associations are only available to authorized election personnel.

Applies to: E2E voting system architectures

10.2.1-D – Election worker selection of indirect associations

When the use of an indirect association is needed, an election worker must select the option for using an indirect association at the beginning of each new voting session.

Applies to: E2E voting system architectures

10.2.1-E – Isolated storage location

Ballots that are not cast and contain an indirect association must be stored in separate storage locations from cast ballots.

Discussion

Ballots that contain an indirect association are not considered cast. Cast ballots and ballots having their eligibility considered need to be kept separate from each other. Although not the only way of meeting this requirement, one example would be storing cast ballots in a different directory from ballots not yet cast.

Applies to: E2E voting system architectures

10.2.1-F – Confidentiality for indirect association

Ballots that are not cast and contain an indirect association must be encrypted.

Discussion

Encryption of the ballot preserves the confidentiality of the voter's ballot selections while the ballot is tied to an indirect association to the voter.

Applies to: E2E voting system architectures
Related requirements: Data Protection

10.2.2 – Identification in vote records

10.2.2-A – Identifiers used for audits

Identifiers used for tying a cast vote record (CVR) and ballot images to physical paper ballots must be distinct from identifiers used for indirect associations.

Discussion

For the purpose of these requirements, associations between physical ballots and CVRs are not considered direct or indirect identifiers.

Related requirements: Auditability

10.2.2-B – No voter record order information

The voting system must not contain data or metadata associated with the CVR and ballot image files that can be used to determine the order in which votes are cast.

10.2.2-C – Identifying information in voter record file names

CVR and ballot image file names must not include any information identifying a voter.

Discussion

This helps to ensure that information that could accidently be used to reference a voter is not used within a file name.

10.2.2-D – Non-memorable identifiers and associations

Unique identifiers and associations must not be displayed in a way that is easily remembered by the voter.

Discussion

Unique identifiers on the paper record are displayed or formatted in such a way that they are not easily remembered by voters, such as by obscuring them in other characters.

Related requirements: 9.4 Efficiency

10.2.2-E – Aggregating and ordering

Aggregated and final totals:

1. must not contain voter specific information, and
2. must not be able to recreate the order in which the ballots were cast.

10.2.2-F – Random number generation

A voting system must generate random numbers using guidance from NIST SP 800-90A rev. 1, *Recommendation for Random Number Generation Using Deterministic Random Bit Generators*.

Discussion

This requirement is important to ensure the use of a cryptographically secure pseudo-random number generator (CSPRNG) and also to ensure any random numbers, such as unique identifiers on a ballot, cannot be used to recreate the order in which a ballot was cast.

To ensure voting system vendors are following the random number generation recommendations in 800-90A revision 1, they will need to submit to the Cryptographic Module Validation Program (CMVP) and the Cryptographic Algorithm Validation Program (CAVP) for conformance testing.

For additional information, see NIST SP 800-90A Rev 1 - Recommendation for Random Number Generation Using Deterministic Random Bit Generators.

Related requirements:	9.1.7-C Random number usage 10.2.2-E Aggregating and ordering
External reference	NIST SP 800-90A Rev 1

10.2.3 – Access to cast vote records (CVR)

10.2.3-A – Least privilege access to store

The directory or storage location of CVRs, ballot images, and ballot selections on the voting system must be subject to the principle of least privilege.

Discussion

NIST SP 800-12 defines “least privilege” as, “The security objective of granting users only those accesses they need to perform their official duties.”
Nieles, Dempsey, and Pilliteri, *Special Publication (SP) 800-12 Revision 1, An Introduction to Information Security*, National Institute of Standards & Technology (NIST), Gaithersburg, Maryland, June, 2017.
https://nvlpubs.nist.gov/nistpubs/SpecialPublications/NIST.SP.800-12r1.pdf

External references:	NIS SP800-12 Revision 1
Related requirements	Access Control

10.2.3-B – Limited access

Permission to access the directory or storage location for CVRs, ballot images, and ballot selections must be assigned to as few entities as possible.

Discussion

Entities include people and applications or processes running on the voting system.

Related requirements Access Control

10.2.3-C – Authorized access

Permissions to access the directory or storage location for CVRs, ballot images, and ballot selections must be validated and explicitly authorized before access is given.

Discussion

Modern operating systems often have sufficient mechanisms in place to accomplish this, but these security capabilities need to be configured and enforced.

Related requirements Access Control

10.2.3-D – Digital voter record access log

The voting system must log all access to the directory or storage location for CVRs, ballot images, and ballot selections in addition to logging access to all actions occurring within the system.

Discussion

This ensures that any person, process, or other entity reading, writing, or performing other actions to the electronic audit trail is properly logged.

Related requirements Access Control, Auditing

10.2.4 – Voter information in other devices and artifacts

10.2.4-A – Voting information in receipts

Receipts produced by a voting system must not contain voter information.

10.2.4-B – Ballot secrecy for receipts

The voting system must not issue a receipt to the voter that would provide proof to another of how the voter voted.

Applies to: E2E voting system architectures

Prior VVSG source: VVSG 2007 - Vol 1: 3.2.3.1-A.4

10.2.4-C – Logging of ballot selections

Logs and other portions of the audit trail must not contain individual or aggregate ballot selections.

Discussion

The voting system needs to be constructed so that the security of the system does not rely upon the secrecy of the event logs. It will be considered routine for event logs to be made available to election officials, and possibly even to the public, if election officials so desire. The system will be designed to permit the election officials to access event logs without fear of negative consequences to the security and integrity of the election. For example, cryptographic secret keys or passwords will not be logged in event log records.

10.2.4-D – Activation device records

Activation devices must not create or retain information that can be used to identify a voter's ballot, including the order and time at which a voter uses the voting system.

Discussion

Information such as the time the voter arrived at the polls or the specific vote-capture device used by the voter may be used to link a voter with their specific ballot and violates the principle of ballot secrecy.

Principle 11
Access Control

The voting system authenticates administrators, users, devices, and services before granting access to sensitive functions.

11.1 - The voting system enables logging, monitoring, reviewing, and modifying of access privileges, accounts, activities, and authorizations.

11.2 - The voting system limits the access of users, roles, and processes to the specific functions and data to which each entity holds authorized access.

11.3 - The voting system supports strong, configurable authentication mechanisms to verify the identities of authorized users and includes multi-factor authentication mechanisms for critical operations.

11.4 - The voting system's default access control policies enforce the principles of least privilege and separation of duties.

11.5 - Logical access to voting system assets are revoked when no longer required.

Principle 11
Access Control

The voting system authenticates administrators, users, devices, and services before granting access to sensitive functions.

The requirements for Principle 11 covers how the voting system secures and limits access to only those who are authorized.

11.1 – Access privileges, accounts, activities and authorizations are logged, monitored, and reviewed and modified as needed ensures there are records in case there are errors or incidents that need to be accounted for. The system also prevents logging any voter ID information and prevents the logging capability from becoming disabled or the log entries from being modified. The system provides administrators access to logs, allowing for continuous monitoring and periodic review.

11.2 – Voting system limits the access of users and processes to the specific functions and data to which each entity holds authorized access

1 – Authorized access ensures that only authorized users can access the voting system, and only administrators can create or modify authorized users, configure permissions and create or assign groups or roles. Control mechanisms distinguish at least four voting stages: Pre-voting, activated, suspended, and post-voting.

2 – Role-based access control standard relates to the requirement that voting systems that implement role-based access control support the ANSI Core Role Based Access Control (RBAC) recommendations. Systems that implement RBAC define groups or roles. Voting systems use the groups and stages described above to assign minimum permissions to authorized users.

11.3 – Voting system supports strong, configurable authentication mechanisms

1 – Access control mechanisms either permit authorized access or prevent unauthorized access to the voting system. This includes the capability to use multi-factor authentication to verify a user's authorized access to perform critical operations. It also authenticates the administrator with a multi-factor authentication mechanism.

2 – User name and password covers the requirement that only the administrator can specify and enforce password strength, histories, and expiration, when that authentication method is used. The system will also compare all passwords against a manufacturer-specified list of well-known weak words, and will ensure that the username is not used in the password.

11.4 – Default access control policies enforce the principles of lease privilege and separation of duties.

11.5 – Logical access to voting system assets are revoked when no longer required. The voting system only allows users access within the time period specified by the administrator. The system locks out roles or individuals after a specified number of consecutive failed attempts, and it allows only an administrator to define the lockout duration.

11.1 - The voting system enables logging, monitoring, reviewing, and modifying of access privileges, accounts, activities, and authorizations.

11.1-A – Logging activities and resource access

The voting system must log any access to, and activities performed on, the voting system, including:

1. timestamps for all log entries
2. all failed and successful attempts to access the voting system
3. all events which change the access control system including policies, privileges, accounts, users, groups or roles, and authentication methods.

Discussion

In the event of an error or incident, the user access log can assist in narrowing down the reason for the incident or error.

- Timestamped log entries will allow for easy auditing and review of access to the voting system.
- Access control logging supports accountability of actions by identifying and authenticating users.
- Groups are a collection of users that are assigned a specific set of permissions. Roles are an identity that is given specific permissions and can be assigned to a user. Any changes to the permissions assigned to groups and roles should be logged to identify updates to a user's privileges.

Prior VVSG source: VVSG 2007 - 4.2.1-A

11.1-B – Voter information in log files

The voting system must prevent the logging of any voter identifying information.

Discussion

The logging and storing of voter identifying information after a ballot is cast violates voter privacy.

Related requirements 10.2.4-C Logging of ballot selections

11.1-C – Preserving log integrity

The voting system must prevent:

1. the logging capability from being disabled, and
2. the log entries from being modified.
3. The deletion of logs; with the exception of log rotation

Discussion

This requirement promotes the integrity of the information logged by ensuring all activities are logged. Additionally, it prevents these abilities from being an option within the user interface.

This requirement promotes the integrity of the information logged by ensuring all activities are not modifiable.

The removal of logs is only appropriate for log rotation, which is when the stored logs are rotated out to create more space for continuous logging. The voting system should be capable of rotating the event log data to manage log file growth. Log file rotation may involve regular (e.g., hourly, nightly, or weekly) moving of an existing log file to some other file name and/or location and starting fresh with an empty log file. Jurisdictions should ensure that the log rotation procedure includes a labeling method to identify the type of log, the system that created the logs, and the date of the logs.

11.1-D – On-demand access to logs

The voting system must provide administrators access to logs on demand, allowing for continuous monitoring and periodic review.

Discussion

Enabling administrators to export and review the logs is a useful feature. Continuous monitoring and review of access control logs gives the administrator the opportunity to analyze and make changes to permissions and privileges, and quickly identify issues.

Prior VVSG source: VVSG 2007 - 4.2.1-A

11.2 - The voting system limits the access of users, roles, and processes to the specific functions and data to which each entity holds authorized access.

11.2.1 – Authorized access

11.2.1-A – Ensuring authorized access

The voting system must allow only authorized users to access the voting system.

Discussion

Authorized users include voters, election officials, and election workers.

11.2.1-B – Modifying authorized user lists

The voting system must allow only an administrator to create or modify the list of authorized users.

Discussion

This requirement assists with ensuring only authorized users are given access to the voting system.

11.2.1-C – Access control by voting stage

The voting system access control mechanisms must distinguish at least the following voting stages from Table 11-1:

1. Pre-voting
2. Activated
3. Suspended
4. Post-voting

Table 11-1 – Voting stage descriptions

Stage	Description
Pre-voting	Powering-on, loading, and configuring device software, maintenance, loading election-specific files, preparing for election day usage
Activated	Activating the ballot, printing, casting, spoiling the ballot
Suspended	Occurring when an election official suspends voting
Post-voting	Closing polls, tabulating votes, printing records, powering-off

Discussion

The groups or roles in 11.2-H (Table 2) will be given specific permissions which can be affected by the voting stage (Table 11-1).

Prior VVSG source: VVSG 1.0 - I.7.2.1, I.7.2.1.1

11.2.1-D – Access control configuration

The voting system must allow only an administrator to configure the permissions and functionality for each identity, group or role, or process to include account and group or role creation, modification, disablement, and deletion.

Discussion

For vote-capture devices, it is possible for each group or role to have (or not have) permissions for every voting stage. Additionally, the permissions that a group or role has for a voting stage can be restricted to certain functions. Table 3 shows an example matrix of group/role to system to voting state access rights; the table is not meant to include all activities. This requirement extends [VVSG2005] I.7.2.1.1-a by allowing configuration flexibility for permissions and functionality for each identity or group/role.

Privileged accounts include any accounts within the operating system, voting device software, or other third-party software with elevated privileges such as administrator, root, and maintenance accounts. This requirement extends [VVSG2005] I.7.2.1.2 by allowing the creation and disabling of privileged accounts.

The administrator is the only user authorized to make major changes within a voting system. Administrators are given this group or role to ensure all other users have proper access to the information necessary to perform their duties.

11.2.1-E – Administrator modified permissions

The voting system must allow only an administrator to create or modify permissions assigned to specific groups or roles.

Discussion

The administrator's authority to create or modify permissions restricts users from gaining unauthorized permissions.

11.2.1-F – Authorized assigning groups or roles

The voting system must allow only an administrator to create or assign the groups or roles.

Discussion

Table 2 is a list of groups or roles that need to be included within the voting system.

Related requirements: 11.2.2-B – Minimum groups or roles

11.2.2 – Role-based access control

11.2.2-A – Role-based access control standard

Voting systems that implement role-based access control must support the recommendations for Core Role Based Access Control (RBAC) in the ANSI INCITS 359-2004 American National Standard for Information Technology – Role Based Access Control document.

Discussion

This requirement extends [VVSG2005] I. 7.2.1.1-a by requiring role-based methods to follow ANSI INCITS 359-2004.

External references: ANSI INCIS 359-2004
Prior VVSG source: VVSG 1.0 - I.7.2.1.1

11.2.2-B – Minimum groups or roles

At minimum, voting systems that implement RBAC must define the following groups or roles within Table 11-2.

Table 11-2 – Minimum Voting System Groups or Roles for RBAC

Group or role	Role description
Administrator	Can update and configure the voting devices and troubleshoots system problems.
Voter	A restricted process in the vote-capture device. It allows the vote-capture device to enter the Activated state for voting activities.
Election Judge	Has the ability to open the polls, close the polls, recover from errors, and generate reports.
Election Worker	Checks in voters and activates the ballot style.
Central Election Official	Loads ballot definition files.

Discussion

Table 11-2 is a baseline list of groups or roles to be included in the voting system.

11.2.2-C – Minimum group or role permissions

At minimum, the voting system must use the groups or roles from Table 11-2 and the voting stages from Table 11-1, to assign the minimum permissions in Table 11-3.

Discussion

Table 11-3 defines the minimum functions according to user, voting stage, and system. Other capabilities can be defined as needed by jurisdiction.

Table 11-3 - Minimum permissions for each group or role

Group/Role	System	Pre-Voting	Activated	Suspended	Post-Voting
Administrator	EMS	Full Access	Full Access	Full Access	Full Access
	BMD/Electronic	Full Access	Full Access	Full Access	Full Access
	PCOS	Full Access	Full Access	Full Access	Full Access
Voter	EMS	---	---	---	---
	BMD/Electronic	---	Vote and cast ballots	---	---
	PCOS	---	Ballot Submission	---	---
Election Judge/Precinct Captain	EMS	---	---	---	---
	BMD/Electronic	Open polls, L&A	Close or suspend polls, Recover from errors	Exit suspended state	Generate reports
	PCOS	Open polls, L&A	Recover from errors	Exit suspended state	Generate reports
Election Worker	EMS	---	---	---	---
	BMD/Electronic	---	Activate ballot and cancel ballots	---	---

	PCOS	---	---	---	---
Central Election Official	EMS	Define and load ballot	---	---	Reconcile provisional-challenged ballots, write-ins, generate reports
	BMD/Electronic	---	---	---	---
	PCOS	---	---	---	---

11.2.2-D – Applying permissions

The voting system must be capable of applying assigned groups or roles and permissions to authorized users.

Discussion

Once the user is assigned a group or role, the voting system needs to be capable of making the necessary changes to the user's permissions. The permissions are changed based on the assigned group or role.

11.3 - The voting system supports strong, configurable authentication mechanisms to verify the identities of authorized users and includes multi-factor authentication mechanisms for critical operations.

11.3.1 – Access control mechanism

11.3.1-A – Access control mechanism application

The voting system must use access control mechanisms to permit authorized access or prevent unauthorized access to the voting system.

Discussion

Access controls support the following concepts:

- Limiting the actions of users, groups or roles, and processes to those that are authorized.
- Limiting entities to the functions for which they are authorized.
- Limiting entities to the data for which they are authorized.
- Accountability of actions by identifying and authenticating users.

Most modern operating systems natively provide configurable access control mechanisms that the voting system application can use.

Prior VVSG source: VVSG 1.1 - I.7.2.1.2-1, I.7.2.1.2-2

11.3.1-B – Multi-factor authentication for critical operations

The voting system must be capable of using multi-factor authentication to verify a user has authorized access to perform critical operations, including:

1. Software updates to the certified voting system
2. Aggregation and tabulation
3. Enabling network functions
4. Changing device states, including opening and closing the polls
5. Deleting or modifying the audit trail
6. Modifying authentication mechanisms

Discussion

NIST SP 800-63-3 Digital Identity Guidelines provides additional information useful in meeting this requirement. NIST SP 800-63-3 defines Multi-factor authentication (MFA) as follows:

"An authentication system that requires more than one distinct authentication factor for successful authentication. Multi-factor authentication can be performed using a multi-factor authenticator or by a combination of authenticators that provide different factors.

The three authentication factors are something you know, something you have, and something you are.

Multifactor authenticators include, but are not limited to the following:

- Username & password
- Smartcard (for example, voter access card)
- iButton
- Biometric authentication (for example, fingerprint)

External reference: NIST SP 800-63-3 Digital Identity Guidelines

11.3.1-C – Multi-factor authentication for administrators

The voting system must authenticate the administrator with a multi-factor authentication mechanism.

Discussion

This requirement extends [VVSG2005] I.7.2.1.2-e by requiring multi-factor authentication for the voting system administrator group or role.

Prior VVSG source: VVSG 1.1 - I.7.2.1.2-e

11.3.2 – Username and password

11.3.2-A – Username and password management

If the voting system uses a username and password authentication method, the voting system must allow only the administrator to enforce password strength, histories, and expiration.

Discussion

This requirement extends [VVSG2005] I.7.2.1.2-e by requiring strong passwords, password histories, and password expiration.

Prior VVSG source: VVSG 1.1 - I.7.2.1.2-1

11.3.2-B – Password complexity

The voting system must, at minimum, meet the password length requirements within NIST SP 800-63B Digital Identity Guidelines standards.

Discussion

NIST SP 800-63B does not specify any additional password complexity requirements besides password length. The recommended minimum password length is 8 characters. NIST's password complexity recommendations are meant to make it easier for users to memorize their passwords, while decreasing user frustration.

11.3.2-B.1 – Specify password complexity

The voting system must allow only the administrator to specify password strength for all accounts.

Discussion

This requirement extends [VVSG2005] I.7.2.1.2-e by allowing the administrator flexibility in configuring password strength. It also requires the use of NIST 800-63B standards.

Prior VVSG source: VVSG 1.1 I.7.2.1.2-1

11.3.2-C – Password blacklist

The voting system must compare all passwords against a manufacturer-specified list of well-known weak passwords.

Discussion

Examples of common weak passwords include 0000, 1111, 1234.

Prior VVSG source: VVSG 1.1 - I.7.2.1.2-1

11.3.2-D – Usernames within passwords

The voting system must ensure that the username is not used in the password.

Discussion

This requirement extends [VVSG2005] I.7.2.1.2-e by restricting the use of usernames and related information in passwords.

Prior VVSG source: VVSG 1.1 - I.7.2.1.2-e

11.4 - The voting system's default access control policies enforce the principles of least privilege and separation of duties.

11.4-A – Least privilege for access policies

By default, the voting system must implement the principle of least privilege including denying access to functions and data unless explicitly permitted.

Discussion

This requirement extends [VVSG2005] I.7.2.1.2-a by requiring explicit authorization of subjects based on access control policies.

Prior VVSG source: VVSG 1.1 - I.7.2.1.2-1

11.4-B – Separation of duties

Voting system documentation must include suggested practices for dispersing critical operations across multiple groups or roles.

Discussion

Guidance for implementing separation of duties within the voting system is imperative to implement the separation of duties principle. Separation of duties is meant to divide user functions and roles so that there is no conflict of interest.

11.5 - Logical access to voting system assets are revoked when no longer required.

11.5-A – Access time period

The voting system must only allow users authorized access within a time period specified by the administrator.

Discussion

After authentication, a user's access to a voting system will time-out after a specified period of time. This will avoid unauthorized access to the voting system by unauthorized users. Once a user's access has timed-out, the user will have to re-authenticate to continue using the voting system.

11.5-B – Account lockout

The voting system must lockout roles or individuals after an administrator-specified number of consecutive failed authentications attempts.

Discussion

This requirement prevents certain classes of password guessing attacks. This requirement can be implemented using a technique such as exponential backoff. Exponential backoff requires that after each unsuccessful authentication attempt, the time period before another authentication attempt can be made grows exponentially. For instance:

- The wait after 1 unsuccessful authentication attempt is 0 seconds
- The wait after 2 unsuccessful attempts is 2 seconds
- The wait after 3 unsuccessful attempts is 4 seconds, and so on

Prior VVSG source: VVSG 1.1 - I.7.2.1.2-1

11.5-C – Lockout time duration

The voting system must allow only an administrator to define the lockout duration.

Discussion

This requirement extends [VVSG2005] I.7.2.1.2 by allowing the administrator flexibility in configuring the account lockout policy. The lockout policy should not lockout voters.

Prior VVSG source: VVSG 1.1 - I.7.2.1.2-1

Principle 12
Physical Security

The voting system prevents or detects attempts to tamper with voting system hardware.

12.1 - The voting system supports mechanisms to detect unauthorized physical access.

12.2 - The voting system only exposes physical ports and access points that are essential to voting operations.

Principle 12
Physical Security

The voting system prevents or detects attempts to tamper with voting system hardware.

The requirements for Principle 12 cover the mechanisms that will ensure the safety of the voting system.

12.1 – Mechanisms to detect unauthorized physical access deals with the requirement that unauthorized physical access leave physical evidence, including access to containers holding voting system records. Devices need to produce an alarm if access to a restricted voting device component is detected or if a connected component is physically disconnected during the activated state. The voting system needs to log when a device or component is connected or disconnected during an activated state and log the status of physical access points when the system is booted.

Locks installed in voting devices for security will be evaluated and meet certain requirements along with being designed with countermeasures to indicate unauthorized attempts have been made to gain access to the voting device. Locking systems will be flexible enough to support different keying schemes. Backup power for power-reliant countermeasures is also required.

12.2 – Physical ports and access points essential to voting operations covers the requirement that voting devices have only those physical ports and access points that are essential to voting operation, testing, and auditing. If a physical connection between components is broken during an activated or suspended state, the affected voting device port will be automatically disabled. Voting system will restrict physical access to any port that accommodates removable media, except for ports that activate a voting session. Devices need to allow authorized administrators to put physical ports into a disabled state. An event entry log that identifies the name of the affected device will be generated when physical ports are enable or disabled.

12.1 - The voting system supports mechanisms to detect unauthorized physical access.

12.1-A – Unauthorized physical access

Any unauthorized physical access must leave physical evidence that an unauthorized event has taken place.

Discussion

Access points such as covers and panels need to be secured by locks or other mechanisms that leave physical evidence in case of tampering or unauthorized access. Manufacturers can provide for and recommend a combination of procedures and physical measures that allow election officials to differentiate authorized from unauthorized access during all modes of operation, such as a system that relies on tamper evident tape, seals, or tags coded with consecutive serial numbers. Other systems might use seals incorporating radio frequency identification devices with physically unclonable functions or other technology in the future.

This requirement extends [VVSG2005] I.7.3.1 by requiring that any tampering with a device leave physical evidence. [VVSG2005] I.7.3.1 states that any tampering should be detectable using manufacturer-specified procedures and measures.

Prior VVSG source: VVSG 1.0 - 7.3.1

12.1-B – Unauthorized physical access alarm

Voting devices must produce an alarm if access to a restricted voting device component is detected during the activated state.

Discussion

This alarm is meant to call attention to election workers in the polling place.

12.1-C – Disconnecting a physical device

The voting device must produce an alarm if a connected component is physically disconnected during the Activated state.

Discussion

Examples of connected components include printers, removable storage devices, and mechanisms used for networking. If a token is necessary for normal operation, such as a memory card or other device granting a voter access to the voting system, it is not necessary to trigger the alarm.

12.1-D – Logging of physical connections and disconnections

The voting system must log when a voting device or component is connected or disconnected during the Activated state.

Discussion

Logging of the devices is vital for determining cause and providing incident information if a physical security event occurs.

Related requirement: Aligns with 15.1, Detection and Monitoring

12.1-E – Logging door cover and panel status

The voting system must log the status (for example, open, closed) of physical access points, such as covers and panels, upon boot of the system.

Discussion

This ensures system owners can monitor access to voting device components whenever they are being used on election day. The status of the open physical access points can be externally monitored and communicated to the voting device itself.

Related requirement: Aligns with 15.1, Detection and Monitoring

12.1-F – Secure containers

Unauthorized physical access to a container holding voting system records must result in physical evidence that an unauthorized event has taken place.

Discussion

The goal is to ensure that election workers or observers would easily notice if someone has tampered with the container. This requirement can be achieved through locks or seals as a part of tamper evidence and tamper resistance countermeasures described by the use procedures and supplied by the manufacturer.

Additionally, to support the auditable principle, containers which hold either paper or electronic voting system records needed for audits need to be secure against physical access.

12.1-G – Secure physical locks

Locks installed in voting devices for security purposes must be:

1. evaluated and meet or exceed requirements of UL 437 for door locks and locking cylinders.

2. designed with countermeasures that give a physical indication that unauthorized attempts have been made to defeat the lock and gain access to the voting device.

Discussion

See [UL03] for UL listing requirements.

External source: UL 437

12.1-H – Secure locking system key

The voting system must support locking systems for securing voting devices that are flexible enough to support different keying schemes, including a scheme that can make use of keys that are unique to each owner.

Discussion

The use of a single key used to unlock thousands of precinct-based voting devices makes for a challenging security situation, as copies of this single key design are distributed to a large number of individuals. This creates a situation in which the key can be easily lost or stolen, and subsequently copied. At the same time, this situation does make key management significantly easier for election officials. To alleviate this situation, election officials might want keying schemes that are more or less restrictive in accordance with their election management practices and needs. This system can make use of replicable locks or cylinders, mechanisms which allow for rekeying of locks, or other technologies. The requirement does not mandate a unique key for each piece of voting equipment, but requires manufacturers to be able to provide unique keys for the voting equipment if requested by election officials. System owners need to establish procedures for issues such as key reproduction, use, and storage.

12.1-I – Backup power for power-reliant countermeasures

Any physical security countermeasure that requires power must have a backup power supply. In addition, switching from primary power supply to backup power supply:

1. produces an alarm, and
2. generates an event log entry.

Discussion

This ensures that the countermeasure isn't disabled or intentionally circumvented by a power failure.

Switching to the backup power supply triggers an alarm that alerts an election worker to the issue so that any problem can be further diagnosed and eventually resolved. The alarm can be visible and audible.

The log entry information is security relevant, especially once a security incident has occurred, and would be useful when determining cause. Alternatively, the voting system should log when there is a switch from backup power to the primary power supply.

Applies to:	Voting Device, EMS
Prior VVSG source:	VVSG 2007 - 5.8.9-A, 5.8.9-B
Related requirement:	Aligns with 15.1, Detection and Monitoring

12.2 - The voting system only exposes physical ports and access points that are essential to voting operations.

12.2-A – Physical port and access least functionality

The voting device must only have physical ports and access points that are essential to voting operations, testing, and auditing.

Discussion

Examples of ports are USB and RJ45 physical network interfaces. Examples of access points are doors, panels, and vents. Voting operations include voting device upgrades and maintenance.

Prior VVSG source: VVSG 2007 - 5.6.3-C

12.2-B – Physical port auto-disable

If a physical connection between voting system components is broken during an activated or suspended state, the affected voting device port must be automatically disabled.

Discussion

Automatically disabling will require an election worker's attention to re-enable and re-attach any network or power cabling. Under ideal circumstances, the specific election worker performing maintenance is uniquely identified within the logs, but this is not required.

12.2-C - Physical port restriction

Voting systems must restrict physical access to voting machine ports that accommodate removable media, with the exception of ports used to activate a voting session.

Discussion

Although voting systems can have ports dedicated to voting operations outside of election day activities, those ports need not be exposed while balloting is in progress. Removable media (such as Floppy, CD or DVD drives, thumb drives, and memory cards) might be essential to voting operations during pre-voting and post-voting phases of the voting cycle, such as machine upgrade, maintenance, and testing. Therefore, all removable media should be accessible only to authorized personnel. They should not be accessible to voters during activated and suspended phases of the voting cycle. It is essential that any removable drives, whether or not they are used by the system, are not accessed without detection.

Related requirements: Aligns with 14.2, System Integrity

12.2-D – Disabling ports

Voting devices must allow authorized administrators to be able to put physical ports into a disabled state.

Discussion

Logically disabling ports prevents unused ports from being used as a staging point for an attack on the voting system.

Applies to:	Voting Device, EMS
Related requirements:	Aligns with 14.2, System integrity

12.2-E – Logging enabled and disabled ports

An event log entry that identifies the name of the affected device must be generated when physical ports are enabled or disabled.

Discussion

Whether a port is disabled or not is security relevant, especially once a security incident has occurred, and this information would be useful when determining cause. 12.2-D applies to physical restrictions, whereas 12.2-F discusses logical disabling of ports.

Applies to:	Voting Device, EMS
Related requirements:	Aligns with 9.3, Access Control and 15.1, Detection and Monitoring

Principle 13
Data Protection

The voting system protects data from unauthorized access, modification, or deletion.

13.1 –The voting system prevents unauthorized access to or manipulation of configuration data, cast vote records, transmitted data, or audit records.

13.2 - The source and integrity of electronic tabulation reports are verifiable.

13.3 - All cryptographic algorithms are public, well-vetted, and standardized.

13.4 - The voting system protects the integrity, authenticity, and confidentiality of sensitive data transmitted over all networks.

Principle 13
Data Protection

The voting system protects data from unauthorized access, modification, or deletion.

The requirements for Principle 13 include ensuring that the voting system prevents unauthorized access to or manipulation of data and records and that the source and integrity of electronic tabulation reports are verifiable. It details cryptographic standards and ensure that the system protects sensitive data that is transmitted over all networks. The sections in **Guideline 13.1 cover**:

1 – Configuration file which deals with the requirement that the system allow only authenticated system administrators to access and modify voting device configuration files. In addition, the election management system (EMS) will uniquely authenticate individuals associated with the role of system administrator before they can access and modify EMS configuration files. Network appliances will uniquely authenticate individuals before allowing them to access and modify configuration files.

2 – Elections records deals with the need for the vote capture and tabulation system and the EMS to integrity protect the cast vote record (CVR) and ballot images when they are stored in the voting device.

13.2 – Source and integrity of electronic tabulation reports are verifiable covers the requirement that cast vote records and ballot images be digitally signed both when stored and before being transmitted. The EMS needs to be able to cryptographically certify all electronic voting records.

13.3 – Cryptographic algorithms are public, well-vetted, and standardized deals with the requirements that cryptographic functionality be implemented in a FIPS 140-2 validated cryptographic module operating in FIPS mode. In addition, cryptographic functions specific to E2E cryptographic voting protocols adhere to requirements set by the certification authority and are omitted from FIPS 140-2 validation. Devices using cryptography need to employ NIST approved algorithms, and the key used with Message Authentication Codes needs to have a specific security strength. Voting system documentation describes how key management is to be performed.

13.4 – Protecting sensitive data transmitted over all networks deals with the requirement that data be transmitted by a mutually authenticated connection. Voting systems transmitting data need to cryptographically protect the confidentiality and integrity of data sent over a network. A receiving voting system will adhere to requirements on verifying and logging data received and presenting any verification errors immediately.

13.1 - The voting system prevents unauthorized access to or manipulation of configuration data, cast vote records, transmitted data, or audit records.

13.1.1 – Configuration file

13.1.1-A – Authentication to access configuration file

The voting system must allow only authenticated system administrators to access and modify voting device configuration files.

Discussion

Voting system configuration files can include operating system and voting system application configuration files. These files can have a large impact on how the voting system functions and what election logic is being used. Therefore, accidental or malicious modification can have a large impact on the system and access to these files should be restricted to authorized individuals.

Prior VVSG source:	VVSG 2007 - 5.3-H
Related requirements:	13.2-A, 13.2-B
Applies to:	Vote capture and tabulation system

13.1.1-B – Authentication to access configuration file on EMS

The EMS must uniquely authenticate individuals associated with the role of system administrator before allowing them to access and modify EMS configuration files.

Discussion

EMS configuration files can include operating system and voting system application configuration files. These files can have a large impact on how an EMS tabulates and reports election results. Therefore, accidental or malicious modification can have a large impact on the system and access to these files should be restricted to authorized individuals.

Prior VVSG source:	VVSG 2007 - 5.3-H.1
Related requirements:	Access Control
Applies to:	EMS workstation

13.1.1-C – Authentication to access configuration file for network appliances

Network appliances must uniquely authenticate individuals before allowing them to access and modify configuration files.

Discussion

Network appliances, such as firewalls, routers, switches, and VPN gateways are generally configurable. Individually authenticating users to the device, in lieu of using a shared password, is a standard practice for restricting access to these devices.

Related requirements: Access Control

Applies to: Network appliance

13.1.2 – Election records

13.1.2-A – Integrity protection for election records

The vote capture and tabulation system must integrity protect the CVR and ballot images when they are stored in the voting device.

13.1.2-B – EMS integrity protection for election records

The EMS must integrity protect the CVR and ballot images when they are stored in the device.

13.2 – The source and integrity of electronic tabulation reports are verifiable.

13.2-A – Signing stored electronic voting records

Cast vote records and ballot images must be digitally signed when stored.

Discussion

Digital signatures address the threat that the records might be tampered with when stored. Cryptographic hashes do not sufficiently mitigate this threat, as election records could be altered and then re-hashed.

Prior VVSG source: VVSG 2007 - 4.3.1-C

13.2-B – Signing electronic voting records prior to transmission

Cast vote records and ballot images must be digitally signed before being transmitted.

Discussion

Digital signatures address the threat that the records might be tampered with when transmitted. Cryptographic hashes do not sufficiently mitigate this threat, as hashed election records could be altered and then the hash could be recomputed.

Prior VVSG source: VVSG 2007 - 4.3.1-C

13.2-C – Cryptographic verification of electronic voting records

The EMS must be able to cryptographically verify all electronic voting records.

Discussion

Verifying the authenticity and integrity record can mitigate attacks that could modify the ballot in transit and allow unauthorized ballots to be counted. This does not solely apply to transmitted records.

Applies to: Vote capture and tabulation system, EMS

13.3 - All cryptographic algorithms are public, well-vetted, and standardized.

13.3-A – Cryptographic module validation

Cryptographic functionality must be implemented in a cryptographic module that meets or exceeds FIPS 140-2 validation, operating in FIPS mode.

This applies to:

1. A software cryptographic module
2. A hardware cryptographic module

Discussion

Use of validated cryptographic modules ensures that the cryptographic algorithms used are secure and their correct implementation has been validated. It also ensures that the security module security requirements have been validated to a specified security level. The current version of FIPS 140 and information about the NIST Cryptographic Module Verification Program are available at: http://csrc.nist.gov/cryptval/. Note that a voting device can use more than one cryptographic module, and quite commonly can use a software module for some functions and a hardware module for other functions. This only applies to the software module – the underlying hardware platform is omitted from this requirement.

External references: FIPS 140
NIST Cryptographic Module Verification Program

Prior VVSG source: VVSG 2007 - 5.1.1-A

Applies to: Cryptographic modules

13.3-B– E2E cryptographic voting protocols

Cryptographic functions specific to E2E cryptographic voting protocols must adhere to requirements set by the certification authority and are omitted from FIPS 140-2 validation.

Discussion

Commonplace cryptographic operations used within E2E systems, such as encryption, decryption, and hashing, are not subject to the FIPS 140-2 validation requirement.

These new types of systems might need additional requirements to be deployed in a secure manner.

External references: FIPS 140-2
Prior VVSG source: VVSG 2007 - 5.1.1-A
Applies to: E2E voting systems

13.3-C – Cryptographic strength

Devices using cryptography must employ NIST approved algorithms with a security strength of at least 112-bits

Discussion

At the time of this writing, NIST specifies the security strength of algorithms in SP 800- 57, Part 1 <http://csrc.nist.gov/publications/nistpubs/index.html>. This NIST recommendation will be revised or updated as new algorithms are added, and if cryptographic analysis indicates that some algorithms are weaker than presently believed. The security strengths of SP 800-57 are based on estimates of the amount of computation required to successfully attack the particular algorithm. The specified strength should be sufficient for several decades.

This requirement is not intended to forbid all incidental use of non-approved algorithms by OS software or standardized network security protocols.

External references: SP 800-57, Part 1
Prior VVSG source: VVSG 2007 - 5.1.1-B

13.3-D – MAC cryptographic strength

The key used with Message Authentication Codes must also have a security strength of at least 112 bits and use a 96-bit tag length.

Discussion

Message Authentication Codes of 96-bits are conventional in standardized secure communications protocols, and acceptable to protect voting records and systems.

Prior VVSG source: VVSG 2007 - 5.1.1-B

13.3-E – Key management documentation

The voting system documentation must describe how key management is to be performed.

Discussion

This document provides procedural steps that can be taken to ease the burden of key management and safely perform these operations.

13.4 - The voting system protects the integrity, authenticity, and confidentiality of sensitive data transmitted over all networks

13.4-A – Mutual authentication of endpoints

Data must only be transmitted by a mutually authenticated connection.

Discussion

Mutual authentication provides assurance that each electronic device is legitimate. Mutual authentication can be performed using various protocols, such as IPsec and SSL/TLS.

Prior VVSG source: VVSG 2007 - 5.6.3-B
Related requirements: Access Control, Detection & Monitoring
Applies to: Voting systems with networking capabilities

13.4-B – Confidentiality protection for transmitted data

A voting system transmitting data must cryptographically protect the confidentiality of all data sent over a network at the transport layer or higher.

Discussion

This does not prevent the use of “double encrypted” connections employing cryptography at multiple layers of the network stack.

13.4-C – Integrity protection for transmitted data

A voting system transmitting data must cryptographically protect the integrity of all election data sent over the network.

Discussion

Integrity protection ensures that any inadvertent or intentional alterations to data are detected by the recipient. Integrity protection for data in transit can be provided through the use of various protocols, such as IPsec VPNs and SSL/TLS.

Applies to: EMS, Vote capture and tabulation system

13.4-D – Verification of election data

A receiving voting system must…

1. Cryptographically verify the integrity and authenticity of all election data received.
2. Immediately log onscreen any verification error of received election results.
3. Immediately present on-screen any verification errors.
4. Not tabulating or aggregating any data that fails verification.

Discussion

This information is a first line of defense against accidental errors or a malicious incident regarding modified or false election records.

This prevents the use of election results that did not pass cryptographic verification.

Applies to: EMS, Vote capture and tabulation system

Principle 14
System Integrity

The voting system performs its intended function in an unimpaired manner, free from unauthorized manipulation of the system, whether intentional or accidental.

14.1 - The voting system uses multiple layers of controls to provide resiliency against security failures or vulnerabilities.

14.2 - The voting system limits its attack surface by avoiding unnecessary code, data paths, connectivity, and physical ports, and by using other technical controls.

14.3 - The voting system maintains and verifies the integrity of software, firmware, and other critical components.

14.4 - Voting system software updates are authorized by an administrator prior to installation.

Principle 14
System Integrity

The voting system performs its intended function in an unimpaired manner, free from unauthorized manipulation of the system, whether intentional or accidental.

The requirements for Principle 14 include ensuring that the voting system provides redundancy against security failures, limits its attack surface, maintains and verifies the integrity of all critical components, and authorizes all software updates before they are installed.

14.1 – Voting system provides redundancy against security failures or vulnerabilities covers the requirement that the system's documentation contains a risk assessment which provides technical controls or a notation showing the acceptable risk for each documented threat to system integrity. This document will describe how all controls work together to prevent, mitigate, and respond to attacks on the system. The system will also document necessary processes that need to occur to ensure integrity of the system.

14.2 – Voting system limits its attack surface by meeting the following requirements. The system will prevent extraneous processes and services from being installed or executed, and will disable networking and non-essential features. The system will visually show an indicator when networking functionality is enabled and disabled and will follow a secure configuration guide for all underlying operating systems and other voting system components.

The system documentation will include the guidance used to ensure the system is securely configured. The system application will not contain unused or dead code. The system's underlying platform will provide and make use of modern exploit mitigation technologies.

The system application will not import entire software libraries where individual functions are more practical. The voting system will have the capability to restrict access to physical ports that are to be used solely by election judges and administrators.

The underlying system platform generally needs to be free of well-known vulnerabilities before certification, unless the certification authority allows it. In that case, a list of these vulnerabilities will be provided to the certification authorities before it is certified.

14.3 – Voting system maintains and verifies the integrity of all critical components covers the requirement that a voting system's documentation contain

- a supply chain risk management strategy
- a list of critical components defined by criticality analysis, and
- hardware and software information for the critical components defined in 14.3-B

1 – Boot integrity deals with the requirement that the voting system cryptographically verifies system integrity before the operating system is loaded into memory. If the system fails boot validation, it will not boot, will provide an onscreen alert, and log this failure along with any information necessary to understand the failure.

2 – Software integrity states that the voting system will only allow digitally signed software and firmware to be installed. The system cryptographically verifies the digital signature before installation and whitelists all application running in userspace. It will also protect the integrity and authenticity of the whitelist configuration files.

14.4 – Software updates are authorized prior to installation covers the requirement that the voting system authenticates administrators:

- before an operating system update
- before a software update to the system application and related hardware
- before a firmware or driver update

14.1 - The voting system uses multiple layers of controls to provide resiliency against security failures or vulnerabilities.

14.1-A – Risk assessment documentation

The voting system's documentation must contain a risk assessment

Discussion

Risk assessments are a foundation of effective risk management. Additionally, they help to facilitate decision making at the organization, business process, and information system levels. Many methods of conducting risk assessments exist, including NIST SP 800-30-1: Guide for Conducting Risk Assessments or ISO/IEC 27005:2011 Information technology -- Security techniques -- Information security risk management.

External references:	NIST SP 800-30-1: Guide for Conducting Risk Assessments ISO/IEC 27005:2011 Information technology -- Security techniques -- Information security risk management
Related requirements:	3.1.3-E – Risk Analysis

14.1-B – Addressing and accepting risk

The voting system's risk assessment documentation must provide technical controls or a notation showing the acceptance of risk for each documented threat to voting system integrity.

Discussion
Assigning controls or accepting risk is a key part of the risk assessment process.

Related requirements: 3.1.3-E – Risk Analysis

14.1-C – System security architecture description

The voting system's risk assessment documentation must describe how physical, technical, and operational controls work together to prevent, mitigate, and respond to attacks on the voting system. This includes the use of:

1. Cryptography
2. Malware protection
3. Firewall access control lists, rules, and configurations
4. System configurations

Discussion
Risk assessments can be large, complicated documents. This requirement ensures that a single narrative exists to explain to election officials and other system owners how the overall security operates for the voting system.

Related requirements: 3.1.3-C – Physical security

14.1-D – Procedural and operational security

The voting system must document necessary procedural and operational processes that need to occur to ensure integrity of the system.

Discussion
Procedural and operational security processes play a key role in overall system security. If any of these procedures are necessary to ensure system integrity or system security, these practices need to be well documented and explained.

14.2 - The voting system limits its attack surface by avoiding unnecessary code, data paths, connectivity, and physical ports, and by using other technical controls.

14.2-A – Extraneous processes and services

The voting system must prevent extraneous processes and services from being installed or executed.

Discussion

Attack surface mitigation limits the voting system's exposure to malicious activity. The presence of non-essential programs or network services severely increases attack surface. This can include network services, superfluous userspace processes, integrated development environment, and compilers.

14.2-B – Non-essential features

The voting system must disable networking and other features that are non-essential to the function of the voting system by default.

Discussion

When the voting system is booted, networking and other functions are prohibited from running. For instance, networking interfaces such as eth, wlan, and hci should be off.

By disabling features that are non-essential to the voting system, this decreases the attack surface by limiting the functionality and decreasing the entry points that may be accessed by unauthorized users.

14.2-C – Network status indicator

The voting system application must visually show an indicator within the management interface when networking functionality is enabled and disabled.

Discussion

This helps to ensure that network functionality is not enabled by accident.

14.2-D – Wireless Communication Restrictions

Voting systems must not be capable of establishing wireless connections.

Discussion

Wireless connections can expand the attack surface of the voting system by opening it up to over-

the-air attacks. Over-the-air access can allow for adversaries to attack remotely without physical access to the voting system. By disallowing wireless capabilities in the voting system, this limits the attack surface and restricts any network connections to be hardwired.

This requirement does not impact or restrict the use of assistive technology (AT) within the polling place. Voters with wireless AT may have to use an adapter that leverages the 3.5 mm headphone jack.

Related requirements: 15.4-B.1 – Documentation for disabled wireless
8.1-E – Standard audio connectors
Applies to: Voting System

14.2-D.1 – Wireless network status indicator

If a voting system has network functionality, the voting system application must visually show an indicator within the management interface when wireless networking functionality is enabled and disabled.

Discussion
Note that this is in addition to the networking identifier.

Wireless is a significant avenue for system compromise. This indicator ensures that wireless functionality is not enabled by accident.

14.2-E – External Network Restrictions

A voting system must not be capable of…

1. establishing a connection to an external network
2. connecting to any device that is capable of establishing a connection to an external network.

Discussion
The basic instructions provided by a vendor should clearly indicate that the intended use and installation of voting systems does not involve any connections to the internet. This requirement is intended to limit the voting systems attack surface and disallow connections of the voting system to technologies such as,

- E-pollbooks,
- Public switched telephone networks (PSTNs), or
- Cellular modems

Internet capabilities within the voting system expands the attack surface even further than other wireless technologies because the data traverses over the internet, which touches all over the world. This type of access allows a malicious actor to attack from various distances, meaning they do not have to be in close proximity of a polling place or near a specific jurisdiction. Exposure to the internet could allow nation-state attackers to gain remote access to the voting system. With remote access an attacker may be able to view all files within a voting system and make modification to files within the voting system. These files may include, election results and ballot records.

This type of exposure could also make voting systems vulnerable to ransomware. Ransomware is a type of malware that could deny access to election data or functionality, usually by encrypting the data with a key known only to the hacker who deployed the malware. Ultimately an attacker, could render a voting system non-operational, until a ransom is paid.

Related requirements: 15.4-B Secure configuration documentation
Applies to: Voting system

14.2-F – Secure configuration and hardening

The voting system must follow a secure configuration guide for all underlying operating systems and other voting system components, with any deviations from best practice documented and justified.

Discussion

Properly configuring an operating system is a difficult and complex task, with small settings potentially causing a large impact. Industry, NIST, and various agencies within the DoD offer guidance for specific operating systems, as do OS and component manufacturers.

Documenting deviations ensures that important settings are not overlooked and decisions to deviate are properly considered.

Related requirements: 15.4-B Secure configuration documentation

14.2-G – Secure configuration and hardening documentation

The voting system documentation must include the guidance used to securely configure the voting system

Discussion

Access to the guidance used for secure configuration provides a reference to ensure the voting system is securely configured.

Related requirements: 15.4-B Secure configuration documentation

14.2-H – Unused code

The voting system application must not contain unused, or dead code.

Discussion

An attacker may be able to take advantage of the unused code and introduce software bugs/exploits that can be used to make the voting system vulnerable.

Dead code is source code that can never be executed in a running program. The surrounding code makes it impossible for a section of code to ever be executed [See MITRE CWE-561-**https://cwe.mitre.org/data/definitions/561.html**]. Software with dead code is considered poor quality and reduces maintainability.

External references: MITRE CWE-561
Applies to: Voting System Application

14.2-I – Exploit mitigation technologies within platform

The underlying platform of the voting system must provide modern exploit mitigation technologies such as Data Execution Prevention (DEP) and Address Space Layout Randomization (ASLR).

Discussion

DEP and ASLR are commonplace exploit mitigation technologies that can help prevent a variety of vulnerability types, including memory corruption errors like buffer overflows.

14.2-J – Application use of exploit mitigation technologies

The underlying platform of the voting system must make use of the exploit mitigation technologies provided by the underlying system.

Discussion

Applications need to be written and compiled in such a way as to make use of underlying exploit mitigation technologies.

14.2-K – Importing software libraries

The voting system application must not import entire software libraries where individual functions are more practical.

Discussion

Importing entire software libraries significantly increases the attack surface of the software. Importing only the functions needed is a useful attack surface minimization strategy. Not all 3rd party libraries are easily modifiable, making this attack surface reduction strategy impractical.

Applies to: Voting System Application

14.2-L – Physical port restriction

The voting system must have the capability to restrict access to physical ports that are meant to be used solely by election judges and administrators.

Discussion

Physical port access needs to be restricted when not in use. This requirement is not meant to impede the use of accessible technology. This requirement assists in restricting adversaries from adding wireless adapters or other malicious adapters to the voting system.

Related requirements: Physical Security
14.2-D – Wireless Communication Restrictions

14.2-M – Known vulnerabilities

The underlying voting system platform must be free of well-known vulnerabilities before certification, unless otherwise noted by the certification authority.

Discussion

Vulnerability scanning tools can be used to identify known vulnerabilities in software and firmware. The U.S. National Vulnerability Database (NVD) is one resource that can be useful for identifying known vulnerabilities. Other vulnerability databases also exist and can be leveraged for full vulnerability coverage that might not be identified by automated scanning tools.

14.2-N – List of known vulnerabilities

If the certification authority allows certification of the voting system with known vulnerabilities, a list of these vulnerabilities must be provided to the certification authority before it is certified.

Discussion

Certain information can also be included for each vulnerability, such as any severity, impact, or exploitability scores.

14.3 - The voting system maintains and verifies the integrity of software, firmware, and other critical components.

14.3-A – Supply chain risk management strategy

The voting system's documentation must contain a supply chain risk management strategy that at minimum includes the following:

1. A reference to the template or standard used, if any, to develop the supply chain risk management strategy
2. Identification and prioritization of the critical systems, components and services
3. The contract language that requires suppliers and partners to provide the appropriate information to meet the assurance requirements of the supply chain risk management strategy. This includes the products or services acquired from the suppliers/partners and any evidence or artifacts that attest to the required level of assurance.
4. The plan for reviewing and auditing suppliers and partners
5. The response and recovery plan for a supply chain risk incident

Discussion

Supply chain risks may include insertion of counterfeits, unauthorized production, tampering, theft, insertion of malicious software and hardware, as well as poor manufacturing and development practices in the technology supply chain. These risks are associated with an organization's decreased visibility into, and understanding of, how the technology that they acquire is developed, integrated, and deployed, as well as the processes, procedures, and practices used to assure the integrity, security, resilience, and quality of the products and services. These risks can be managed by…

- Following Appendix E of NIST SP 800-161 – Supply Chain Risk Management Practices for Federal Information Systems and Organizations guidance, Appendix E provides a supply chain management plan(strategy) template.
- Utilizing the NIST Cybersecurity Framework version 1.1. by referencing the Supply Chain Risk Management category and subcategory
- Referencing the relevant security controls for supply chain in NIST SP 800-53 Rev. 5 *Security and Privacy Controls for Information Systems and Organizations*

External references: NIST SP 800-161 – Supply Chain Risk Management Practices for Federal Information Systems and Organizations

NIST Cybersecurity Framework Version 1.1
NIST SP 800-53 Rev. 5

14.3-B – Criticality analysis

The voting system's documentation must include a list of critical components defined by a criticality analysis.

Discussion

Defining the critical components of the voting system can assist in prioritizing their importance to the voting process and identifying the impact to security, privacy and performance for failure or compromise.

This can be supplemented by following NISTIR 8179 *Criticality Analysis Process Model - Prioritizing Systems and Components.*

External references: NISTIR 8179 – Criticality Analysis Process Model – Prioritizing Systems and Components

14.3-B.1 –Bill of Materials

The voting system's documentation must include the hardware and software information for the critical components defined in the 14.3-B and at minimum list the following information for each component:

1. Component name
2. Manufacturer
3. Model or Version
4. Applicable platform for software (e.g., Windows or Linux)

Discussion

This requirement will use the critical components defined in the critical analysis of 14.3-B.

This is a common practice when providing a hardware bill of materials. It is not as common to produce a bill of materials for software and as standards/best practices are developed, they should be considered for inclusion in the software bill of materials.

External references: SAFECode - Security Risks Inherent in the Use of Third-party Components

14.3.1 – Boot integrity

14.3.1-A – Cryptographic boot verification

The voting system must cryptographically verify system integrity before the operating system is loaded into memory.

Discussion

This requirement does not mandate hardware support. This requirement could be met by trusted boot, but other software-based solutions exist. This includes a software bootloader cryptographically verifying the OS prior to execution. Verifying the bootloader itself is excluded from this requirement, but not prohibited.

Applies to: Vote capture and tabulation device, EMS

14.3.1-B – Preventing of boot on error

If the voting system fails boot validation, the voting system must not boot and provide an onscreen alert.

Discussion

System users need to be notified when the voting system is either corrupted or has been maliciously modified.

Boot validation prevents unauthorized operating systems and software from being installed or run on a system.

Applies to: Vote capture and tabulation device, EMS

14.3.1-C – Logging of verification failure

The voting system must log if the voting system does not pass boot validation and include any other necessary information to understand the failure.

Discussion

Failure of boot validation needs to be logged so these errors can be further analyzed when needed.

Applies to: Vote capture and tabulation device, EMS

14.3.2 – Software integrity

14.3.2-A – Installing software

The voting system must only allow digitally signed software and firmware to be installed.

Discussion

Signed software and firmware ensures that it is not modified before installation, and that it is being distributed by the proper entity.

14.3.2-B – Software verification for installation

The voting system must cryptographically verify the digital signature of software and firmware before it is installed.

Discussion

The security properties of integrity and authenticity are not achieved unless the digital signature for the signed software and firmware is cryptographically verified.

14.3.2-C – Software whitelisting

The voting system must whitelist all applications running in userspace.

Discussion

This is the principle malware prevention mechanism on the voting system. One method of achieving this is cryptographically verifying the digital signatures of all applications before they are run on the voting system.

Applies to: Vote Capture Device

14.3.2-D – Integrity protection for software whitelists

The voting system must protect the integrity and authenticity of the whitelist configuration files.

Discussion

If the whitelist is improperly modified, the software whitelisting mitigation can be defeated. The most common way of providing whitelist configuration file protection could be a digital signature.

Applies to: Vote Capture Device

14.4 - Voting system software updates are authorized by an administrator prior to installation.

14.4-A – Authenticated operating system updates

The voting system must authenticate administrators before an operating system update is performed.

Discussion

Administrators are required to be authenticated before they can update the voting system, regardless of whether the updated done by a networked method or performed using physical media.

Related requirements:	Access Control
Applies to:	Vote Capture Device

14.4-B – Authenticated application updates

The voting system must authenticate administrators before a software update to the voting system application and related software.

Discussion

Administrators are required to be authenticated before they can update the voting system, whether the update is applied by a network method or physical media.

Related requirements:	Access Control
Applies to:	Vote capture and tabulation device, Network appliances, EMS

14.4-C – Authenticated firmware updates

The voting system must authenticate administrators before a firmware or driver update.

Discussion

Administrators are required to be authenticated before they can update the voting system, regardless if network enabled update is performed or via physical media.

Related requirements:	Access Control
Applies to:	Vote Capture Device

Principle 15
Detection and Monitoring

The voting system provides mechanisms to detect anomalous or malicious behavior.

15.1 - Voting system equipment records important activities through event logging mechanisms, which are stored in a format suitable for automated processing.

15.2 - The voting system generates, stores, and reports all error messages as they occur.

15.3 - The voting system is designed to protect against malware.

15.4 - A voting system with networking capabilities employs appropriate, well-vetted modern defenses against network-based attacks, commensurate with current best practice.

Principle 15
Detection and Monitoring

The voting system provides mechanisms to detect anomalous or malicious behavior.

The requirements for Principle 15 include ensuring that voting system equipment records important activities through event logging, and generates and reports all error messages as they occur. The system employs mechanisms to protect against malware. Systems with networking capabilities employ defenses against network-based attacks.

15.1 – Voting system equipment records important activities through event logging mechanisms covers the requirements that the system be capable of logging events that occur in a voting system and of exporting those logs. The system will not log any information identifying a specific voter or connecting a voter to a specific ballot. At a minimum, the system will log events including:

- general system functions
- networking
- software
- voting functions

In addition, when a system administrator is accessing a configuration file, the system needs to log identifying information about the individual and group or role accessing that file.

15.2 – Voting system generates, stores, and reports all error messages as they occur covers the requirement that systems provide immediate notification to the user when an error occurs and that system documents include procedures for handling errors, including logging all errors and creating error reports.

15.3 – Voting system employs mechanisms to protect against malware deals with the requirement that vote capture and tabulation devices verify software using digital signatures or application whitelisting. The sections in 15.3.1 cover requirement specific to malware protection mechanisms.

1 – Malware protection mechanisms deals with the need for COTS devices that provide EMS functionality to:

- deploy mechanisms to protect against malware
- promptly notify an election official when malware is detected
- provide notification upon the removal or remediation of malware

The system's malware protection mechanisms need to be updatable and the documentation needs to include the process and procedures for performing the updates. The voting system will log instances when it detects malware along with malware remediation activities.

15.4 – Voting system with networking capabilities employs appropriate defenses against network-based attacks deals with the requirement for system documentation to include the network architecture of any internal network used by any portion of the voting system. Documentation also lists security relevant configurations and is accompanied by network security best practices. The system includes a firewall or intrusion detection system (IDS). Default configurations for the system implement the principle of least privilege. In addition, the system needs to be capable of updating rules and policies for firewalls and other network appliances.

15.1 - Voting system equipment records important activities through event logging mechanisms, which are stored in a format suitable for automated processing.

15.1-A – Event logging

The voting system must be capable of logging events that occur in a voting system.

Discussion

The ability to log events within a system allows for continuous monitoring of the voting system. These logs provide a way for administrators to analyze the voting system's activities, diagnose issues, and perform necessary recovery and remediation actions.

15.1-B – Exporting logs

The voting system must be capable of exporting logs.

Discussion

Exporting logs offers the opportunity for external review, clearing storage, and a method to compare with future logs.

15.1-C – Logging voter information

The voting system must not log any information:

1. identifying a specific voter
2. connecting a voter to a specific ballot

Discussion

No voter information is stored anywhere within voting system logs. This would violate voter ballot secrecy because it can link a voter to their ballot selections.

Related requirements: 11.1-B and Ballot secrecy

15.1-D – Logging event types

At minimum, the voting system must log the events included in Table 15-1.

Discussion

Table 15-1 provides a list of events that will be included in the voting system event logs. The voting system is not limited to the events in the table.

Related requirements Access Control, System Integrity, Data Protection

Table 15-1 – System events to log

System Event	Description	Applies To
General system functions		
Device generated error and exception messages	Includes but is not limited to: • The source and disposition of system interrupts resulting in entry into exception handling routines. • Messages generated by exception handlers. • The identification code and number of occurrences for each hardware and software error or failure. • Notification of physical violations of security. • Other exception events such as power failures, failure of critical hardware components, data transmission errors, or other types of operating anomalies. • All faults and the recovery actions taken. Device generated error and exception messages such as ordinary timer system interrupts and normal I/O system interrupts do not need to be logged.	Programmed device
Critical system status messages	Critical system status messages other than information messages displayed by the device during the course of normal operations. Includes but is not limited to: • Diagnostic and status messages upon startup • The “zero totals” check conducted before opening the polling place or counting a precinct centrally	Programmed device

	• For paper-based systems, the initiation or termination of scanner and communications equipment operation • Printer errors • Detection or remediation of malware or other malicious software • Cryptographic boot validation success/failure	
Non-critical status messages	Non-critical status messages that are generated by the device's data quality monitor or by software and hardware condition monitors.	Programmed device
Events that require election official intervention	Events that require election official intervention, so that each election official access can be monitored, and access sequence can be constructed.	Programmed device
Device shutdown and restarts	Both normal and abnormal device shutdowns and restarts.	Programmed device
Changes to system configuration settings	Configuration settings include but are not limited to registry keys, kernel settings, logging settings, and other voting device configuration settings.	Programmed device
Integrity checks for executables, configuration files, data, and logs.	Integrity checks that can indicate possible tampering with files and data.	Programmed device with file systems
The addition and deletion of files.	Files that are added or deleted from the voting device.	Programmed device with file systems
System readiness results	Includes but is not limited to: • System pass or fail of hardware and software test for system readiness • Identification of the software release, identification of the election to be processed, polling place identification, and the results of the software and hardware diagnostic tests • Pass or fail of ballot style compatibility and integrity test • Pass or fail of system test data removal • Zero totals of data paths and memory locations for vote recording	Programmed device
Removable media events	Removable media that is inserted into or removed from the voting device.	Programmed device
Backup and restore	Successful and failed attempts to perform backups and restores.	Election Management Systems

Authentication and Access Control

Authentication related events	Includes but is not limited to: • Login/logoff events (both successful and failed attempts) • Account lockout events • Password changes	Programmed device
Access control related events	Includes but is not limited to: • Use of privileges (such as a user running a process as an administrator) • Attempts to exceed privileges • All access attempts to application and underlying system resources • Changes to the access control configuration of the voting device	Programmed device
User account and role (or groups) management activity	Includes but is not limited to: • Addition and deletion of user accounts and roles • User account and role suspension and reactivation • Changes to account or role security attributes such as password length, access levels, login restrictions, and permissions • Administrator account and role password resets	Programmed device
Networking		
Enabling or disabling networking functionality	Includes but is not limited to: • Wired networking • Wireless networking	Programmed device
Software		
Installing, upgrading, patching, or modifying software or firmware	Logging for installation, upgrading, patching, or modifying software or firmware include logging what was installed, upgraded, or modified as well as a cryptographic hash or other secure identifier of the old and new versions of the data.	Programmed device
Changes to configuration settings	Includes but is not limited to: • Changes to critical function settings. At a minimum, critical function settings include location of election definition file, contents of the election definition file, vote reporting, location of logs, and voting device configuration settings. • Changes to device settings including, but not limited to, enabling and disabling services. • Starting and stopping processes.	Programmed device
Abnormal process exits	All abnormal process exits.	Programmed device
Successful and failed database connection attempts (if a database is used).	All database connection attempts.	Programmed device with database capabilities

Cryptographic Functions		
Changes to cryptographic keys	At a minimum, critical cryptographic settings include key addition, key removal, and re-keying.	Programmed device
Voting Functions		
Ballot definition and modification	During election definition and ballot preparation, the device can provide logging information for preparing the baseline ballot formats and modifications to them, including a description of the modification and corresponding dates. Includes but is not limited to: • The account name that made the modifications. • A description of what was modified including the file name, location, and the content changed. • The date and time of the modification.	Programmed device
Voting events	Includes: • Opening and closing polls • Casting a vote • Canceling a vote during verification • Success or failure of log and election results exportation • Note: for paper-based devices, these requirements might need to be met procedurally	Programmed device

15.1-E – Configuration file access log

When a system administrator is accessing a configuration file, the voting system must log identifying information of the individual and group or role accessing that file.

Discussion

A record of who modified a configuration file is important for auditing and accountability. The identifying information should include the username or the name of the user.

15.2 - The voting system generates, stores, and reports all error messages as they occur.

15.2-A – Presentation of errors

The voting system must provide immediate notification to the user when an error occurs.

Discussion

Immediate notification of an issue or an error allows for prompt recovery and remediation.

15.2-B – Documenting error handling

The voting system documentation must include procedures for handling errors.

Discussion

Documentation will assist election officials with steps to properly address errors.

15.2-C – Logging errors

The voting system must log all errors.

15.2-D – Creating error reports

The voting system must be capable of creating error reports.

Discussion

Error reports allow system administrators to easily analyze the errors that occurred within a system.

15.3 - The voting system is designed to protect against malware.

15.3-A – Software verification

Vote capture and tabulation devices must verify software using digital signatures, application whitelisting, or some combination of the two.

Discussion

Digital signatures and whitelists assist in ensuring the vote capture and tabulation devices are using the correct software. If unauthorized software is found on the device, the appropriate malware remediation and response procedures will be implemented.

Related requirements: System Integrity, Data Protection

Applies to: Vote capture and tabulation devices

15.3.1 – Malware protection

15.3.1-A – Malware protection mechanisms

COTS devices providing EMS functionality must deploy mechanisms to protect against malware.

Discussion

NIST SP 800-83 Revision 1 *Guide to Malware Incident Prevention and Handling for Desktops and Laptops* might be useful as supplemental guidance for protecting against malware. Digital signatures and whitelists can also be useful protection mechanisms.

External reference: NIST SP 800-83 Revision 1 Guide to Malware Incident Prevention and Handling for Desktops and Laptops

Applies to: EMS Workstations

15.3.1-B – Updatable malware protection mechanisms

The voting system's malware protection mechanisms must be updatable.

Discussion

Malware protection mechanisms typically use software signatures to identify malware. As new malware signatures are received, the malware protection mechanism needs to be updated with the new signatures to ensure it is identifying all known malware.

Applies to: EMS Workstations, vote capture and tabulation devices

15.3.1-C – Documenting malware protection mechanisms

The voting system documentation must include the process and procedures for updating malware protection mechanisms.

Discussion

Providing documentation of the procedures to configure the malware protection mechanisms assists with ensuring the malware protection mechanisms are properly updated to meet *15.3.1-B-Updatable malware protection mechanisms.*

Applies to: EMS Workstations, vote capture and tabulation devices

15.3.1-D – Notification of malware detection

COTS devices providing EMS functionality must promptly notify an election official when malware is detected.

Discussion

Malware on an EMS device can disrupt the integrity of the data on the EMS device. Notification of malware detection allows election officials to promptly take the proper action to avoid data integrity issues.

Applies to: EMS Workstations

15.3.1-E – Logging malware detection

The voting system must log instances of detecting malware.

15.3.1-F – Notification of malware remediation

COTS devices providing EMS functionality must provide a notification upon the removal or remediation of malware.

Discussion

Once malware it is identified on a device, operations can cease until the malware is remediated. This notification allows administrators and officials to know when it is safe to resume normal operations.

Applies to: EMS Workstation

15.3.1-G – Logging malware remediation

The voting system must log malware remediation activities.

15.4 - A voting system with networking capabilities employs appropriate, well-vetted modern defenses against network-based attacks, commensurate with current best practice.

15.4-A – Network architecture documentation

The voting system documentation must include the network architecture of any internal network used by any portion of the voting system.

Discussion

Documentation of the network architecture can assist with data flow analysis, proper network configuration, and architecture to properly support the voting system.

Applies to: Voting systems with networking capabilities

15.4-B – Secure configuration documentation

The voting system documentation must list security relevant configurations and be accompanied by network security best practices.

Discussion

This documentation may include how external network services are not included as part of the voting system and are handled through a separate air-gapped process. For example, a sneaker-net process may be used to manually transfer elections results to another system that uses public telecommunications to transmit the unofficial election results to a central count center.

A variety of documentation providing secure configurations for network devices is publicly available from the US government.

If outside manufacturers provide guidance and best practices exist, these need to be documented and used to the extent practical.

Applies to: Voting systems with networking capabilities

15.4-B.1 – Documentation for disabled wireless

The voting system documentation must include information about how wireless is disabled within the voting system.

Discussion

Documentation for how the voting system is configured to disable wireless networking is important to meet requirement 14.2-D, which disallows the use of any wireless connections. Example information for how wireless can be disabled may include the following:

- A system configuration process that disables wireless networking devices
- Disconnecting/unplugging wireless device antennas
- Removing wireless hardware within the voting system

A variety of documentation providing secure configurations for network devices is publicly available from the US government.

If outside manufacturers provide guidance and best practices exist, these need to be documented and used to the extent practical.

Related requirements: 14.2-D Wireless Communication Restrictions

Applies to: Voting systems with networking capabilities

15.4-C – Firewall and IDS

The voting system may include a firewall or intrusion detection system (IDS).

Discussion

This requirement does not include point-to-point networks which do not typically use network appliances. Firewalls and IDSs are typically used to control and monitor the boundary between a private network and the internet. Although the current requirements do not allow for internet connectivity, firewalls and IDSs may also be used for internal boundaries and monitoring inside a private network.

Applies to: Voting systems with networking capabilities

15.4-D – Least privilege

Default configurations for the voting system must implement the principle of least privilege.

Discussion

Network access is only as much as is necessary to perform the desired function.

Related requirements Access Control

Applies to: Voting systems with networking capabilities

15.4-E – Rule and policy updates

The voting system must be capable of regularly updating rules and policies for firewalls and other network appliances.

Discussion

Network appliances and the voting system are constantly receiving improvements and information related to current threats. As this information is released, rules and policies might need to be modified to adjust to new capabilities.

Applies to: Voting systems with networking capabilities

Appendix A
Glossary of Terms

Glossary

A:

absentee ballot

Ballot used for **absentee voting**.

Synonyms: mail ballot, postal ballot

absentee voting

Voting that can occur unsupervised at a location chosen by the **voter** either before or on **election day**.

Synonyms: all-mail voting, mail voting, postal voting, vote-by-mail

acceptance testing

Examination of a **voting system** and by the purchasing **election jurisdiction** to validate:

- the performance of delivered **devices** to ensure they meet procurement requirements, and
- that the delivered system is, in fact, the certified system purchased.

This usually happens in a simulated-use environment.

access control

The process of granting or denying specific requests to:

- obtain and use information and related information processing services; and
- enter specific physical facilities.

accessibility

Measurable characteristics that indicate the degree to which a system is available to, and usable by, individuals with disabilities. The most common disabilities include those associated with vision, hearing, mobility, and cognition.

accreditation

Formal recognition that a laboratory is competent to carry out specific **tests** or calibrations.

accreditation body

1. Authoritative body that provides **accreditation**.
2. Independent organization responsible for
    - assessing the performance of other organizations against a recognized **standard**, and
    - formally confirming the status of those that meet the standard.

activation device

Programmed device that creates credentials necessary to begin a **voting session** using a specific **ballot style**. Examples include **electronic poll books** and card activators that contain credential information necessary to determine the appropriate ballot style for the **voter**.

active period

Span of time during which a **vote-capture device** either is ready to begin a **voting session** or is in use during a voting session.

adjudication

Process of resolving flagged **cast ballots** to reflect **voter intent**. Common reasons for flagging include:

- write-ins,
- **overvotes**,
- marginal **machine-readable mark**,
- having no **contest selections** marked on the entire **ballot**, or
- the ballot being unreadable by a scanner.

adjudication-required ballot

A **ballot** that contains **contest selections** that require **adjudication**.

air gap

A physical separation between systems that requires data to be moved by some external, manual procedure.

alert time

The amount of time that a **voting device** will wait for detectible **voter** activity after issuing an alert, before going into an inactive state requiring **election worker** intervention.

alternative format

The **ballot** or accompanying information is said to be in an alternative format if it is presented in non-standard ballot language and format. Examples include, but are not limited to, languages other than English, Braille, ASCII text, large print, recorded audio.

appropriate mark

An **expected mark** made according to the **ballot instructions**.

approval voting

A **vote variation** used for **elections** in which each **voter** may "approve" of (that is, select) any number of **candidates**. Typically, the winner is the most-approved candidate.

archival media

Storage media that is designed to preserve content for an extended period of time with minimal data corruption or loss.

assistive technology

A **device** that improves or maintains the capabilities of people with disabilities (such as no vision, low vision, mobility, or cognitive). These devices include headsets, keypads, software, sip-and-puff, and voice synthesizers.

asymmetric cryptography

Encryption system that uses a public and **private key** pair for cryptographic operation. The private key is generally stored in a user's **digital certificate** and used typically to encrypt or digitally sign data. The **public key** is used typically to decrypt the data or verify its **digital signatures**. The keys could be used interchangeably as needed, that is, a public key can be used to encrypt data and the private key can be used to decrypt the data.

audio format

A **ballot display format** in which **contest options** and other information are communicated through sound and speech.

Synonyms: audio ballot

audit

1. Systematic, independent, documented process for obtaining **records**, statements of fact, or other relevant information and assessing them objectively to determine the extent to which specified requirements are fulfilled.
2. Verification of statistical or exact agreement of records from different processes or subsystems of a **voting system**.
3. A review of a system and its controls to determine its operational status and the accuracy of its outputs.

audit device

Voting device dedicated exclusively to independently verifying or assessing the **voting system**'s performance.

audit trail

Information **recorded** during **election** activities to reconstruct steps followed or to later verify actions taken with respect to the **voting system**.

authentication

Verifying the identity of a user, process, or **device**, often as a prerequisite to allowing access to resources in an information system. **Audit trails** may include event logs, paper **records**, error messages, and **reports**.

B:

ballot

Presentation of the **contest options** for a particular **voter**.

ballot counting logic

The software logic that

- defines the combinations of **contest selections** that are valid and invalid on a given **ballot** and,
- determines how the contest selections are totaled in a given **election**.

ballot data

A list of **contests** and associated options that may appear on a **ballot** for a particular **election**.

ballot display format

The concrete presentation of the contents of a **ballot** appropriate to the particular voting technology being used. The contents may be rendered using various methods of presentation (visual or audio), language, or graphics.

ballot image

Electronically produced **record** of all **votes cast** by a single **voter**. A ballot image might be a transient logical representation of the votes or an archival record (a **cast vote record**).

ballot instructions

Information provided to the **voter** that describes the procedure for marking the **ballot**. This information may appear directly on the paper or electronic ballot or may be provided separately.

ballot manifest

A catalog prepared by **election officials** listing all the physical **paper ballots** and their locations in sequence.

ballot marking device

A **device** that:

- permits **contest options** to be reviewed on an electronic interface,

- produces a human-readable **paper ballot**, and
- does not make any other lasting **record** of the **voter**'s selections.

Synonyms: BMD, EBM, electronic ballot marker

ballot measure

A question that appears on a **ballot** with options, usually in the form of an approval or rejection.

Synonyms: ballot issue, ballot proposition, ballot question, referendum

ballot measure option

A **contest option** that specifies a response to a **ballot measure**.

ballot on demand®

A process that produces a **paper ballot** of the required **ballot style** that meets a specific **voter**'s needs. The use of this process requires:

- a system with a printer that can create a tabulatable paper ballot; and
- a **device** driving the printer that has all the data needed to print each ballot style and allows selection of the needed style.

Note: "ballot on demand" is a registered trademark of ES&S.

Synonyms: BOD

ballot production

Process of generating **ballots** for presentation to **voters**, for example, printing **paper ballots** or configuring the ballot presentation for an electronic display.

ballot rotation

The process of varying the order of listed **candidates** within a **contest**. This allows each candidate to appear first on the list of candidates an approximately equal number of times across different **ballot styles** or **election districts**.

ballot style

Ballot data that has been put into **contest** order for a particular **precinct** and considers a particular set of **voter** situations. Voter situations include party affiliation (for **closed primaries**), and age of the voter (in states that permit 17-year-olds to **vote** in **primary elections**), among others.

barcode

An optical, machine-readable representation of data as a sequence of bars and spaces that conform to accepted **standards**. Linear (1d) barcode standards include UPC, EAN and 128. QR is an example of a 2D barcode standard.

barcode reader

Device used to scan **barcodes** and convert the encoded information into a usable format. Barcode readers are used to scan codes on a variety of **election** materials including **ballots**, driver's licenses, voter ID cards, voter information packets, envelopes, and other election documents.

batch

A collection of **paper ballots** gathered as a group for tabulation or for auditing.

batch-fed scanner

An electronic **voting device** that:

- accepts stacks of hand-marked or BMD-produced **paper ballots** and automatically processes them until the stack is empty;
- is usually used at an **election jurisdiction**'s central location;
- is mostly commonly used to process **absentee ballots**;
- usually has input and output hoppers for **ballots**;
- scans a ballot and rejects it if either unreadable or un-processable;
- detects, interprets, and validates **contest selections**;
- detects and sorts (either digitally or physically) ballots that are unreadable or un-processable, or that contain undeterminable selections, marking exceptions, or write-ins; and
- **tabulates** and **reports contest** results as required.

This unit was previously referred to as central count optical scanner or CCOS.

Synonyms: CCOS, central tabulator, central-count optical scanner, high-speed optical scanner

benchmark

Quantitative point of reference to which the measured performance of a system or **device** may be compared.

blank ballot

An issued **ballot** without any selections made.

Synonyms: unmarked ballot

C:

callable unit

(Of a software program or logical design) Function, method, operation, subroutine, procedure, or analogous structural unit that appears within a **module**.

candidate

Person contending in a **contest** for **office**. A candidate may be explicitly presented as one of the **contest options** or may be a write-in candidate.

candidate option

A **contest option** that is associated with a **candidate**.

canvass

The process of compiling, reviewing, and validating **election** returns that forms the basis of the official results by a **political subdivision**.

cast

(v) The final action a **voter** takes in selecting **contest options** and irrevocably confirming their intent to **vote** as selected.

cast ballot

Ballot in which the **voter** has taken final action in selecting **contest options** and irrevocably confirmed their intent to **vote** as selected.

Synonyms: voted ballot

cast vote record

Archival tabulatable **record** of all **votes** produced by a single **voter** from a given **ballot**.

Synonyms: CVR

central reporting device

Electronic **voting device** that consolidates and **reports vote** totals from multiple **precincts** at a central location.

certification testing

Testing of a **voting system** performed by a testing authority (such as the EAC or a state) to ensure that the system meets the requirements defined in the **standards** being tested against in the manner specified in its product documentation.

ciphertext

Data or information in its encrypted form.

closed primary

Partisan primary election in which the **voter** receives a **ballot** containing only those **party-specific contests** pertaining to the **political party** with which the voter is affiliated, along with **non-party-specific contests** presented at the same election. Unaffiliated voters may be permitted to **vote** only on non-party-specific contests.

combined precinct

Two or more **precincts** treated as a single precinct for a specific **election**.

Synonyms: consolidated precinct, super precinct

commercial-off-the-shelf

Hardware or software **components** that are widely available for purchase and can be integrated into special-purpose systems.

Synonyms: COTS

common data format

Standard and practice of creating and storing data in a common, described format that can be read by other systems.

Synonyms: CDF

Common Industry Format

Format used for **usability test** reporting. The format is described in ISO/IEC 25062:2006 "Common Industry Format (CIF) for Usability Test Reports," one of a group of usability **standards**. CIF is the format required for usability test reporting.

Synonyms: CIF

component

Element within a larger **voting system**.

confidentiality

Prevention of unauthorized disclosure of information.

configuration management

A continuous process of recording and maintaining consistent and reliable **records** pertaining to an organization's **hardware** and software composition, including software version control and hardware updates.

conformance

Fulfilling specified requirements by a product, process, or service.

conformance testing

Process of testing **device** or system of devices against the requirements specified in one or more **standards**. The outcomes of a **conformance test** are generally a pass or fail result, possibly including **reports** of problems encountered during the execution.

Synonyms: conformity assessment

contest

A single decision or set of associated decisions being put before the **voters** (for example, the option of **candidates** to fill a particular public **office** or the approval or disapproval of a constitutional amendment). This term encompasses other terms such as "race," "question," and "issue" that are sometimes used to refer to specific kinds of contests. It does not refer to the legal challenge of an **election** outcome.

contest option

A votable choice that appears under a **contest**.

contest option position

A specified area on a **ballot** where a **voter**'s selection in a particular **contest** can be indicated.

Synonyms: ballot marking target area, ballot selection position, target, target area

contest option vote

Vote that will be **tabulated** for a particular **contest option**. This term was previously referred to as **valid vote**.

contest selection

A selection made on the **ballot** by a **voter** with respect to a specific single **contest** (for example, a **candidate**, the value "Yes" or "Approve").

core logic

Subset of application logic that is responsible for **vote** recording and tabulation.

corrective action

Action taken to eliminate the causes of an existing deficiency or other undesirable situation in order to prevent it from recurring.

counted ballot

A **read ballot** that has been processed and whose **votes** are included in the vote totals.

Synonyms: tabulated ballot, tallied ballot

cross-party endorsement

Endorsement of a single **candidate** or slate of candidates by more than one **political party**. The candidate or slate appears on the **ballot** representing each endorsing political party.

Synonyms: cross filing

cryptographic end-to-end voting system

A **voting system** that supports both **voter** verification and election verification.

Synonyms: E2E

cryptographic hash

A cryptographic algorithm that computes a numerical value based on a data file or electronic message. The numerical value is used to represent that file or message, and depends on the entire contents of the file or message. A hash function can be considered to be a fingerprint of the file or message. Colloquially known as a hash, hash function, or digital fingerprint. Hashes provide integrity protection.

cryptographic key

A numeric value used as input to cryptographic operations, such as **decryption**, **encryption**, signature generation, or verification of a **digital signature**.

cryptography

Discipline that embodies the principles, means, and methods for transforming data to hide their semantic content, prevent their unauthorized use, prevent their undetected modification, or establish their authenticity.

cumulative voting

A **vote variation** used in **multi-seat contests** where a **voter** is permitted to distribute allowed selections to 1 or more **candidates** in whole **vote** increments.

cybersecurity

Measures taken to protect computer systems and data from attack and unauthorized access or use.

D:

decertification

Revocation of national or state certification of a **voting system** or any of its **components**.

decryption

Cryptographic process of transforming encrypted data back into its pre-encryption form.

defense-in-depth

Also called the "Castle" approach. Multiple levels of logical and physical security measures that deny a single point of security **failure** in a system. Examples include the combined use of passwords, **encryption**, lock-and-key access, security seals, and logs.

device

Physical apparatus and any supporting supplies, materials, and logic that together form a functional unit that performs assigned tasks as an integrated whole.

digital certificate

A data set used to identify the holder of the certification and to verify, using a PKI, the authenticity of the certificate. It typically includes the holder's **private key** and is used for cryptographic operations such as digitally signing or encrypting data.

digital signature

A cryptographic operation where the **private key** is used to digitally sign an electronic document and the **public key** is used to verify the signature. Digital signatures provide data **authentication** and integrity protection.

direct recording electronic voting machine

A **vote-capture device** that allows:

- electronic presentation of a **ballot**,
- electronic selection of valid **contest options**, and
- electronic storage of **contest selections** as individual **records**.

It also provides a summary of these contest selections.

Synonyms: DRE

dynamic password

A password that changes at a defined interval or event.

E:

early voting

Voting that occurs prior to **election day** under the supervision of **election workers**.

Synonyms: in-person absentee voting

early voting center

Physical location where individuals may **cast** a **ballot** before **election day** under the supervision of **election workers**.

Synonyms: early vote center

elected office

An **office** that is filled primarily or exclusively via **election**.

election

A formal process in which qualified **voters** select **candidates** to fill **seats** in one or more **offices** and/or **vote** on one or more proposed **ballot measures**.

Election Assistance Commission

Election Assistance Commission, created by the **Help America Vote Act** (HAVA) to assist the states regarding HAVA compliance and to distribute HAVA funds to the states. The EAC is also charged with creating **voting system** guidelines and operating the federal government's first voting system certification program. The EAC is also responsible for maintaining the National Voter Registration form, conducting research, and administering a national clearinghouse on **elections** that includes shared practices, information for **voters**, and other resources to improve elections.

Synonyms: EAC

election certification

The act of confirming the final official results of a jurisdiction's **election**. This event occurs after results from valid **ballots** are tallied from all sources (**election day**, **absentee voting**, **early**

voting, **provisional ballots**, etc.) and results are validated and approved by those legally responsible.

election day

The last day on which **voters** may **cast** a **ballot**. **Absentee ballots** and **early voting** ballots may be cast in advance of election day.

election definition

Data used in defining an **election**, including **election districts**, **contests**, **candidates**, and **ballot style** information.

election definition medium

Programmed memory **device** containing all applicable **election definition** data required by the **election system component** where the device will be used.

election district

Administrative area in which **voters** are entitled to **vote** in **contests** that are specific to that area.

election jurisdiction

A geographical area to which a practical authority has been granted to administer **elections** for political or administrative **offices**. Areas of jurisdiction apply to local, state, and federal levels. States, counties, cities, **towns**, and **townships** are all examples of jurisdictions.

election management system

Set of processing functions and databases within a **voting system** typically used to:

- develop and maintain **election definition** data,
- perform **ballot** layout functions,
- create ballot presentation templates for ballot printers or **devices** used by **voters** for ballot markup,
- **tabulate votes**,
- consolidate and **report** results, and
- maintain **audit trails**.

Synonyms: EMS

election official

Any person who is involved with administering or conducting an **election**, including government personnel and temporary **election workers**. This may include any county clerk and recorder, election judge, member of a **canvassing** board, central election official, **election day** worker, member of a board of county commissioners, member or secretary of a board of directors authorized to conduct public elections, representative of a governing body, or other person engaged in the performance of election duties as required by the election code.

Synonyms: EO

election programming

Process by which **election officials** or their designees use **voting system software** to create the **election definition** and configure all **election definition medium** for use in a specific **election**.

election results report

A **tabulation report** produced after the closing of **polls** for the purpose of publicizing the vote counts.

Election Results Reporting System

A system that:

- aggregates and displays **election** results across the **election jurisdiction**,
- can be real-time or near real-time,
- can provide a variety of formats for displaying election results, and
- may provide direct feeds for the media.

Synonyms: ENR, ERR, election night reporting

election system

1. A technology-based system that is used to collect, process, and store data related to **elections** and election administration. In addition to **voter** registration systems and public election websites, election systems include **voting systems**, **vote** tabulation systems, **electronic poll books**, **election results reporting systems**, and auditing **devices**.
2. Entire array of procedures, people, resources, equipment, and locations associated with conducting elections.

election worker

Any person who interacts with those coming to **vote**. This includes any **poll** worker, **election day** worker, **early voting** worker, or other temporary staff engaged in supporting the voting or vote counting process.

electronic ballot delivery

The delivery of **ballot** and **voter** information packets electronically. The MOVE Act requires each state to provide for the electronic delivery (via fax, email, or an Internet-supported application) of ballots and related information from the local election office to the registered **UOCAVA voter**.

electronic ballot interface

Subsystem within a **voting system** which communicates **ballot** information to a **voter** in video, audio, or other **alternative format** which allows the voter to select **contest options** using vocalization or physical actions.

electronic ballot return

The return of a **voted ballot** or **voter** information packet using electronic means. This can be by fax, email, or through the use of an Internet supported application. Sometimes referred to as "Internet Voting."

electronic device

Device that uses electronic or electromechanical **components**.

electronic poll book

Device that partially automates the process of checking in **voters**, assigning them the correct **ballot style**, and marking voters who have been issued a **ballot**. May be used in place of a traditional paper **poll** book. E-poll books can be stand alone at the **precinct** with a separate copy of the registration list or can be networked into a central voter registration system. They can check and update voter **records** in real time.

Synonyms: EPB, e-poll book

electronic voter interface

Component of an electronic **vote-capture device** that communicates **ballot** information to the **voter** and accepts **contest selection** input from the voter.

eligible voters

The universe of all **voters** who, if they **cast** a **ballot**, would have the legal right to have eligible **contests** on that ballot **tabulated**. This would include those who do not appear in the list of eligible voters because they live in a same-day registration or no registration state and did not or could not register ahead of time.

encryption

Cryptographic process of transforming data (called "plaintext") into a form (called "**ciphertext**") that conceals the data's original meaning to prevent it from being known or used. Encryption provides **confidentiality** protection.

endorsement

Approval by a **political party**, for example, as the **candidate** that the party fields in a particular **contest** or as the candidate that should receive straight party **votes**. In some states, more than one party may endorse a candidate or **contest option**.

enhanced visual format

An alternative visual display format supporting personal choices such as text size, color contrast, and preferred language.

error correction code

Coding system that allows data being read or transmitted to be checked for errors and, when detected, corrects those errors.

error rate

Ratio of the number of errors that occur to the volume of data processed.

escalation of privilege

An attack on a system where the attacker is using some means to bypass **security controls** in order to attain a higher privilege level on the target system.

exhausted ballot

Refers to processing a **ranked choice voting contest** on a **cast ballot**, when that **ballot** becomes inactive and cannot be advanced in the tabulation for a contest because there are no further valid rankings on the ballot for continuing **contest options**.

expected mark

Mark that falls wholly or partially inside a **contest option position**.

eXtensible markup language

A text-based language used to organize and present information on the World Wide Web.

Synonyms: XML

extraneous mark

A mark on a **paper ballot** that appears to be unrelated to the act of indicating a **voter**'s selection. Examples include: a mark made unintentionally by a voter that is obviously not related to making a selection; a hesitation mark, a dot within or outside of the **contest option position** made by resting a pen or pencil on the **ballot**; written notes or identifying information not related to indication of the voter's selection; or printing defects.

Synonyms: inadvertent mark, random mark, stray mark

F:

failure

Looking at **voting system** reliability, a failure is an event that results in:

- loss of one or more functions,
- degradation of performance resulting in a **device** that is unable to perform its intended function for longer than 10 seconds,
- automatic reset, restart, or reboot of the **voting device**, operating system or application software, requiring an unanticipated intervention by a person in the role of **election worker** or technician before normal operation can continue, or
- error messages or audit log entries indicating that a failure has occurred.

failure rate

Ratio of the number of **failures** that occur to the volume of data processed.

fault

Flaw in design or implementation that may result in the qualities or behavior of the **voting system** deviating from the qualities or behavior that are anticipated, including those specified in the VVSG or in manufacturer-provided documentation.

fault-tolerant

A system that continues to operate after the **failure** of a computer or network **component**.

Federal Information Processing Standards

Standards for federal computer systems developed by NIST. These **standards** are developed when there are no existing industry standards to address federal requirements for system **interoperability**, portability of data and software, and computer security.

Synonyms: FIPS

finding

(n) Result of a formal evaluation by a **test** lab or accredited expert.
Synonyms: verdict

firewall

A gateway system designed to prevent unauthorized access to a private network or intranet that is connected to the internet. A firewall can be implemented in either **hardware** or software, or a combination of both.

firmware

A specific class of software encoded directly into a **hardware device** that controls its defined functions and provides the low-level control for the computer's specific hardware (such as the firmware that initially boots an operating system).

functional configuration audit

Exhaustive verification of every system function and combination of functions cited in the **manufacturer**'s documentation. The FCA verifies the accuracy and completeness of the system's Voter Manual, Operations Procedures, Maintenance Procedures, and Diagnostic Testing Procedures.

Synonyms: FCA

functional test

Test performed to verify or validate the accomplishment of one or more functions.

G:

general election

Election in which all **eligible voters**, regardless of party affiliation, are permitted to select **candidates** to fill public **office** and/or **vote** on **ballot measures**.

geographical information system

A system designed to capture, store, manipulate, analyze, manage, and present all types of spatial or geographical data. GIS systems are used to validate voting district boundaries and may be integrated with the voter registration system.

Synonyms: GIS

geopolitical unit

Describes units of geopolitical geography so that they can be associated with **contests**, **offices**, **ballot styles**, and **election** results.

Synonyms: GpUnit

H:

hardware

The physical, tangible, mechanical, or electromechanical **components** of a system.

Help America Vote Act

Act passed by the U.S. Congress in 2002 to make sweeping reforms to the nation's **voting process**. HAVA addresses improvements to **voting systems** and **voter** access that were identified following the 2000 **election**.

Synonyms: HAVA

I:

implementation statement

Statement by a **manufacturer** indicating the capabilities, features, and optional functions as well as extensions that have been implemented.

Synonyms: implementation conformance statement

in-person voting

Voting that occurs in an official location under the supervision of **election workers**.

independently

Without assistance from an **election worker** or other person.

indirect selection

The mechanism by which a selection for a specific **contest option** automatically selects other linked contest options. An example is a straight party selection that causes indirect selections for all contest options of the identified party.

information security

Protecting information and information systems from unauthorized access, use, disclosure, disruption, modification, or destruction in order to provide integrity, **confidentiality**, and availability.

Synonyms: IS

inspection

Examination of a product design, product, process, or installation and determination of its conformity with specific requirements.

interaction mode

A specific combination of display format and control or navigation options that enable **voters** to perceive and interact with the **voting system**.

interoperability

The extent to which systems from different **manufacturers** and **devices** with different system configurations can communicate with each other.

intrusion detection system

A **hardware** or software application that detects and **reports** a suspected security breach, policy violation, or other compromise that may adversely affect the network.

Synonyms: IDS

K:

key management

Activities involving handling of **cryptographic keys** and other related security parameters (such as passwords) during the entire **life cycle** of the keys, including their generation, storage, establishment, entry and output, zeroization, and revocation.

L:

life cycle

Systems engineering concept that identifies the phases that a system passes through, from concept to retirement. There are different concerns and activities associated with each phase of the life cycle.

locality

Generic term used in **election** contexts to signify a **town**, village or city contained within an **election jurisdiction**, such as a county.

logic and accuracy testing

Equipment and system readiness **tests** whose purpose is to detect malfunctioning **devices** and improper election-specific setup before the equipment or systems are used in an **election**. **Election officials** conduct L&A tests prior to the start of an election as part of the process of setting up the system and the devices for an election according to jurisdiction practices and conforming to any state laws.

Synonyms: L&A, LAT

logic defect

Fault in software, **firmware**, or hardwired logic.

logical correctness

Condition signifying that, for a given input, a computer program will satisfy the program specification and produce the required output.

low/no dexterity mode

An **interaction mode** with **accessibility** features for **voters** with no use of one or both hands or low dexterity.

M:

machine-readable mark

Mark in a **contest selection** position of a **paper ballot** that meets requirements for detection by a scanner.

machine-unreadable mark

Mark in a **contest selection** position of a **paper ballot** that cannot be detected as readable or marginal by a scanner, and may require human **adjudication**.

majority voting

A **vote variation** which requires the winning **candidate** to receive more than half of the **votes cast**. If no candidate wins an outright majority, a **runoff election** may be held between the top two vote-getters.

malware

Software or **firmware** intended to perform an unauthorized process that will have adverse impact on the **confidentiality**, integrity, or availability of a system. For example, a virus, worm, Trojan horse, or other code-based entity that infects a host. Spyware and some forms of adware are also examples of malware.

Synonyms: malicious code

manually-marked paper ballot

Paper ballot marked by a **voter** using a writing utensil. The paper ballot is the independent **voter verifiable record**.

Synonyms: MMPB

manufacturer

Entity with ownership and control over a **voting system** submitted for testing.

marginally machine-readable mark

An intentional mark in a **contest selection** position of a **paper ballot** that does not meet the requirements for a reliably detectable selection, and therefore requires human **adjudication**. A marginal mark may be determined to indicate a selection, depending on state law.

Synonyms: marginal mark

marked ballot

Ballot that contains all of a **voter**'s selections.

military voter

A member of a uniformed service in active service, including army, navy, air force, marine corps, coast guard and merchant marine, and their spouses and dependents.

misfeed rate

Ratio of the misfeed total to the total **ballot** volume.

module

A structural unit of a software program that serves a specific function for the program or that serves to make the program modular in structure for the purposes of easier understanding and maintenance.

multi-factor authentication

Authentication mechanism requiring two or more of the following:

- something you know (such as a password),
- something you have (such as a **token**),
- something you are (for example, biometric authentication).

multi-seat contest

Contest in which multiple **candidates** are elected to fill a specified number of **seats**.

municipality

Term as used in **election** contexts to signify a jurisdiction such as city, **town**, or village that has some form of local government for which elections are generally conducted.

N:

N-of-M voting

Vote variation in which the **voter** is entitled to allocate a fixed number of **votes** (N) over a list of M **contest options** or **write-in options**, with the constraint that at most 1 vote may be allocated to a given contest option. This usually occurs when multiple **seats** are concurrently being filled in a governing body such as a city council or school board where **candidates** contend for at-large seats. The voter is not obliged to allocate all N votes. 1-of-M is N-of-M voting where N = 1.

national certification test report

Report of the results of independent testing of a **voting system** by a **Voting System Test Lab** (VSTL) delivered to the EAC with a recommendation about granting a certification number.

National Institute of Standards and Technology

Federal organization tasked with assisting in the development of **voting system standards**. NIST develops and maintains standards for a wide array of technologies. NIST scientists assist the EAC in developing testable standards for voting systems.

Synonyms: NIST

non-party-specific contest

Contest where eligibility to **vote** in that contest is independent of **political party** affiliation.

non-user-serviceable failure

Functional **failure** that requires the **manufacturer** or highly trained personnel to repair.

nonpartisan office

Elected office for which **candidates** appear on the **ballot** without **political party** designation.

nonpartisan primary

Primary election held to narrow the field of **candidates** in **non-party-specific contests**.

nonvolatile memory

Memory in which information can be stored indefinitely with no external power applied.

notice of clarification

Document providing further guidance and explanation on the requirements and procedures of the EAC's **Voting System** Certification or Voting System Testing Lab (**VSTL**) programs. NOCs may be issued in response to a clarification request from a Voting System Test Lab or an EAC registered **manufacturer**. EAC may also issue NOCs when it determines general clarifications are necessary.

O:

observational test

Operational **test** conducted on **voting devices** during an **election** by real **voters** to establish confidence that the **voter verifiable** paper **record** is produced correctly when **assistive technology** is used. Devices subjected to observational testing are used for normal collection of **votes**; the votes collected are included in the election tally.

office

A position established by law with certain associated rights and duties.

open primary

Partisan primary election in which the **voter** may choose a **political party** at the time of voting and **vote** in **party-specific contests** associated with that party, along with **non-party-specific contests** presented at the same election. Some states require voters to publicly declare their choice of party at the **polling place**, after which the **election worker** provides or activates the appropriate **ballot**. Other states allow the voters to make their choice of party within the privacy of the voting booth.

Synonyms: pick-your-party primary

open source

Computer software with its **source code** (human readable code) made available with a license in which the copyright holder provides the rights to study, change, and distribute the software to anyone and for any purpose. Open source software may:

- be developed in a collaborative public manner;
- be reviewed by multiple professional and amateur programmers;
- require a fee and be licensed like other software;
- be fully open source or may have only a portion of the software open source.

optical scan

Voting system that **tabulates votes** marked in **contest option positions** on the surface of a **paper ballot**.

overseas voter

A U.S. citizen who is living outside of the United States and is eligible to **vote** in their last place of residence in the United States.

overvote

Occurs when the number of selections made by a **voter** in a **contest** is more than the maximum number allowed.

Synonyms: over-vote

P:

paper ballot

A piece of paper, or multiple sheets of paper, on which all **contest options** of a given **ballot style** are printed.

paper ballot sheet

A single piece of paper that forms part of a **paper ballot**. Paper ballots may contain multiple sheets.

paper ballot side

The face of a **paper ballot sheet**. A **paper ballot** may have two sides.

partisan office

Elected office for which **candidates** may appear on the **ballot** with a **political party** designation.

partisan primary

Primary election held to narrow the field of **candidates** in **party-specific contests**.

party-specific contest

Contest where eligibility to **vote** in that contest is restricted based on **political party** affiliation or lack of any affiliation. The affiliation might be the registered affiliation of the **voter** or it might be an affiliation declared at the time of voting.

pattern voting

Selecting **contest options** across multiple **contests** in a predetermined pattern intending to signal one's identity to someone else. The possibility of pattern voting can be an issue for publishing **Cast Vote** Records (CVR) because it may compromise **voter** privacy if there are enough selections in each published CVR to make it likely a selection pattern might be unique.

penetration testing

An evaluation method that enables researchers to search for vulnerabilities in a system.

Synonyms: Pen Testing

personal assistive device

Assistive technology belonging to **voters** rather than any supplied with the **voting system**.

personal identifiable information

Any information about an individual maintained by an agency, including:

- information that can be used to distinguish or trace an individual's identity, such as name, social security number, date and place of birth, mother's maiden name, or biometric **records**; and
- any other information that can be linked to an individual, such as medical, educational, financial, and employment information.

Synonyms: PII

physical configuration audit

Inspection by a **voting system test lab** (VSTL) that compares the **voting system components** submitted for **certification testing** to the **manufacturer**'s technical documentation and confirms that the documentation submitted meets the national certification requirements. Includes witnessing the executable system being built to ensure that the certified release is built from the **tested** components.

Synonyms: PCA

plurality voting

A **vote variation** in which the **candidate** with the most **votes** wins, without necessarily receiving a majority of votes.

political party

An association of individuals under whose name a **candidate** may appear on a **ballot**.

political subdivision

Any unit of government, such as counties, cities, school districts, and water and conservation districts having authority to hold **elections** for public **offices** or on **ballot measures**.

polling location

Physical address of a **polling place**.

polling place

Location at which **voters** may **cast** in-person **ballots** under the supervision of **election workers** during one or more specific time periods.

Synonyms: poll, polling station

post-election tabulation audit

A post-election **audit** that involves hand-counting a sample of **votes** on paper **records**, then comparing those **counts** to the corresponding vote totals originally **reported**:

- as a check on the accuracy of **election** results, and
- to detect discrepancies using accurate hand counts of the paper records as the **benchmark**.

precinct

Election administration division corresponding to a geographic area that is the basis for determining which **contests** the **voters** legally residing in that area are eligible to **vote** on.

Synonyms: polling district, tabulation district

precinct count

Counting ballots in the same **precinct** in which those **ballots** have been **cast**.

precinct split

A subdivision of a **precinct** which arises when a precinct is split by two or more **election districts** that may require different **ballot styles**.

Synonyms: split, split precinct, sub-precinct

presentable ballot style

Ballot style that includes all presentational details required to generate a **ballot**. This may include language, ordering of **contests** and **candidates**, and structural content such as headers.

presidential primary election

Primary election in which **voters** choose the delegates to the presidential nominating conventions allotted to their states by the national party committees.

primary election

Election held to determine which **candidates** qualify to appear as **contest options** in subsequent elections.

privacy (for voters)

A property of a **voting system** that is designed and deployed to enable **voters** to obtain a **ballot**, and mark, verify, and **cast** it without revealing their ballot selections or selections of language, display and **interaction modes** to anyone else. This does not preclude the ability of a voter to request assistance under state law.

private key

The secret part of an asymmetric key pair that is typically used to verify, digitally sign, or decrypt data.

product standard

Standard that specifies requirements to be fulfilled by a product or a group of products, to confirm it can perform its intended task.

programmed device

Electronic device that includes software. Most electronic **voting devices** include application logic (software) and are, therefore, programmed devices.

proportional voting

A **vote variation** used in **multi-seat contests** where the **votes** allowed in the **contest** are distributed to the selected **candidates** proportionally depending on the number of selections. This may result in candidates receiving fractional votes.

provisional ballot

A failsafe **ballot** provided to a **voter** whose eligibility for a regular ballot cannot be immediately determined. The ballot may be **counted** or further processed depending on state law.

Synonyms: affidavit ballot

public key

Public part of an asymmetric key pair that is typically used to verify **digital signatures** or encrypt data.

public key infrastructure

A set of roles, policies, and procedures used to establish greater trust in the authenticity of a **digital certificate** and for use in creating, managing, distributing, using, storing, and revoking digital certificates.

Synonyms: PKI

public test

An abbreviated logic and accuracy **test** of voting equipment, pre-announced in public media and open to public attendance, usually in **conformance** with specific **election** calendar timing.

Q:

quick response code

A 2D, trademarked barcode. Some **voting systems** will encode the **voter**'s selections in a QR Code that can be read on a scanner in the **precinct** and converted to a printed **ballot**.

Synonyms: QR Code

R:

range voting

A **vote variation** for single-seat **contests**, in which **voters** give each **candidate** a score, the scores are added (or averaged), and the candidate with the highest total is elected.

ranked choice voting

A **vote variation**:

- which allows each **voter** to rank **contest options** in order of the voter's preference,
- in which **votes** are **counted** in rounds using a series of runoff tabulations to defeat contest options with the fewest votes, and,
- which elects a winner with a majority of final round votes in a single-winner **contest** and provides proportional representation in multi-winner contests.

Synonyms: IRV, RCV, instant run-off voting, ranked order

read ballot

Cast ballot that has been successfully accepted and initially processed.

Synonyms: scanned ballot

recall issue with options

Vote variation that allows **voters** to remove elected representatives from **office** before their terms of office expire. The recall may involve not only the question of whether a particular officer should be removed, but also the question of naming a successor in the event that there is an affirmative **vote** for the recall.

recallable ballot

Recorded ballot that can be individually retrieved and included or excluded from further processing.

recertification

Re-examination, and possibly retesting, of a **voting system** that was modified after being previously certified. The object of recertification is to determine if the system as modified still conforms to the requirements.

record

(n) Preserved evidence of activities performed or results achieved (for example, forms, **reports**, **test** results).
(v) To create a record.

recorded ballot

A **ballot** for which there is an associated **cast vote record**.

recount

Repeat tabulation of **votes cast** in an **election**, whether manually or electronically, that is used to determine the accuracy of an initial count.

report

Self-contained, time-stamped, archival **record**, such as a printout or analogous electronic file that is produced at a specific time and subsequently protected from modification.

report total error rate

Ratio of the **report** total error to the report total volume.

reporting unit

Geographical area in which **reported** totals or counts are reported (for example, an **election jurisdiction**, **precinct**, or **election district**).

reproducibility

Ability to obtain the same **test** results by using the same **test method** on identical test items in different testing laboratories with different operators using different equipment.

residual vote

Vote that could not be allocated to a specific **contest** due to an **undervote** or **overvote**.

reviewed ballot

Ballot that has been reviewed (either electronically or by the **voter**) before it is **cast**, to determine what **contest selections** it contains.

risk assessment

The process of identifying the risks to system security and determining the probability of occurrence, the resulting impact, and safeguards that would mitigate this impact.

risk-limiting tabulation audit

Post-election tabulation audit procedure for checking a sample of **ballots** (or **voter verifiable records**) that is guaranteed to have a large, pre-specified chance of correcting the **reported** outcome if the reported outcome is wrong (that is, if a full hand count would reveal an outcome different from the reported outcome).

Synonyms: RLA

runoff election

Election to select a winner following a **primary election** or a **general election**, in which no **candidate** in the **contest** received the required minimum percentage of the **votes cast**. The two candidates receiving the most votes for the contest in question proceed to a runoff election.

S:

seat

An **elected office** position that a single officeholder may occupy for a term of **office**.

second chance voting

Feature of a **voter-facing scanner** that reviews the **ballot** for possible marking mistakes, informs the **voter**, and presents an opportunity to **cast** as-is or return the ballot.

security analysis

An inquiry into the potential existence of security flaws in a **voting system**. Includes an analysis of the system's software, **firmware**, and **hardware**, as well as the procedures associated with system development, deployment, operation, and management.

security controls

Management, operational, and technical controls (that is, safeguards or countermeasures) prescribed for an information system to protect the **confidentiality**, integrity, and availability of the system and its information.

security strength

A metric associated with the amount of work (that is, the number of operations) that is required to break a cryptographic algorithm or system.

software independence

Quality of a **voting system** or **voting device** where a previously undetected change or **fault** in software cannot cause an undetectable change or error in **election** outcome.

Synonyms: SI

source code

Human readable computer instructions that, when compiled or interpreted, define the functionality of a **programmed device**. Source code can be written by humans or by computers.

spear phishing

A targeted attack by hackers, using bogus emails, that attempts to get the victim to provide login information or personal information to the hackers. Spear Phishing attempts may appear to originate from legitimate, known sources, such as organizational IT or known vendors.

special election

Primary election or **general election** that is not regularly scheduled. A special election may be combined with a scheduled **election**.

spoil

(A **ballot**) To mark or otherwise alter a ballot so it indicates in a human-readable manner that the ballot is not to be **cast**.

spoiled ballot

A **ballot** that has been issued to a **voter** but will not be **cast**, usually because it has been incorrectly marked or impaired in some way.

standard

A document that provides requirements, specifications, guidelines, or characteristics that can be used consistently to ensure that materials, products, processes, and services are fit for their purpose.

straight party override

Explicit **voter** selection that overrides or supplements the **vote** selections made by a **straight party voting** option. Straight party overrides may be subject to state **election** rules for how they work or whether they are allowed.

straight party voting

Mechanism that allows **voters** to **cast** a single **vote** to select all **candidates** on the **ballot** from a single **political party**.

street segment data

The portion of a street between two consecutive cross streets that can be assigned to a **precinct**.

support software

Software that aids in developing, maintaining, or using other software, for example, compilers, loaders and other utilities.

symmetric cryptography

Encryption system that uses the same key for encryption and **decryption**. This key must be kept secret.

Synonyms: secret key cryptography

system extent

Administrative unit that is the entire scope within which the **voting system** is used (for example, a county). The system extent corresponds to the top-level reporting context for which the system generates **reports**.

T:

t-coil

Inductive coil used in some hearing aids to allow reception of an audio band magnetic field signal instead of an acoustic signal. The magnetic or inductive mode of reception is commonly used in conjunction with telephones, auditorium loop systems, and other systems that provide the required magnetic field output.

tabulate

Process of totaling **votes**.

Synonyms: count

tabulation report

A **report** containing the counts associated with **ballots** tabulated for a given **election district**.

tactile controls

Tactile controls are discernable or perceptible by touch using hands, feet, or other parts of the body. (Does not include touch screens.) Dual switches are a form of tactile controls that can be used by **voters** with minimal use of their hands.

technical data package

Manufacturer documentation relating to the **voting system**, which can include manuals, description of **components**, and details of architectural and engineering design.

Synonyms: TDP

test

Procedure used to determine one or more characteristics of a given product, process, or service according to a specified procedure for **conformity assessment**. A test may be an operational test or a non-operating test (for example, an **inspection**).

test deck

A set of marked ballots with a predetermined outcome. Used for **logic and accuracy testing** of a **voting system**.

test method

Specified technical procedure for performing a **test**, procedures by which tests are derived, or a combination of these.

test plan

Document created prior to testing that outlines the scope and nature of testing, items to be **tested**, test approach, resources needed to perform testing, test tasks, risks, and schedule.

test suite

Implementation of a set of operational **tests** for a particular object (such as a specific **voting system**) or class of objects (such as all voting systems that can interpret the language in which the test data are expressed).

third-party logic

Software, **firmware**, or hardwired logic that is neither application logic nor **COTS**. This includes, for example, general-purpose software developed by a third party that is either customized (for example, ported to a new platform, as is Windows Embedded Compact), not widely used, or source-code generated by a COTS package.

token

Something a user possesses and controls, typically a key or password, that is used to authenticate an identity.

Synonyms: authentication token, cryptographic token

touch screen voting machine

A **vote-capture device** that utilizes a computer screen to display the **ballot** and allows the **voter** to indicate their selections by touching designated locations on the screen.

town

An urban area that has a name, defined boundaries, and local government, and that is generally larger than a village and smaller than a city. Term used in New England, New York, and Wisconsin to refer to the equivalent of the **civil township** in these states.

township

A widely used unit of local government in the United States, subordinate to a county, with some form of local government for which it generally conducts **elections**.

Synonyms: civil township

U:

undervote

Occurs when the number of **voter** selections in a **contest** is less than the maximum number allowed for that contest or when no selection is made. The number of undervotes is equal to the number of **votes** lost, for example, if no selection is made in a vote for two contest the number of votes lost is two.

Synonyms: under-vote

Uniformed and Overseas Citizens Absentee Voting Act

Act of Congress in 1986 requiring that the states and territories allow certain groups of citizens to register and **vote** absentee in **elections** for Federal **offices**.

Synonyms: UOCAVA

UOCAVA voter

An **overseas voter** or an active duty member of the U.S. military, either within or outside the United States, including any accompanying spouse and family members who are eligible to **vote** in their last place of residence in the United States. The **Uniformed and Overseas Citizens Absentee Voting Act** is commonly referred to as UOCAVA.

usability

Effectiveness, efficiency, and satisfaction with which a specified set of users can achieve a specified set of tasks in a particular environment. Usability in the context of **voting** refers to **voters** being able to **cast valid votes** as they intended quickly, without errors, and with confidence that their **contest selections** were **recorded** correctly. It also refers to the usability of the setup and operation of voting equipment in the **polling place**.

usability testing

Testing that encompasses a range of methods that examine how users in the target audience actually interact with a system, in contrast to analytic techniques such as **usability inspection**.

user-serviceable failure

Functional **failure** that can be remedied by a troubleshooter or **election official** using only knowledge found in voting equipment user documentation.

V:

valid vote

See **contest option vote**.

validation

Process of evaluating a system or **component** during or at the end of the development process to determine whether it satisfies specified requirements.

visual format

A display format in which **contest options** and other information are displayed on screen or paper for perception using sight.

vote

Indication of support for a particular **contest option**.

vote center

A physical location where **voters** from multiple **precincts** may **cast** their **ballots**.

vote for N-of-M

A **multi-seat contest** in which **voters** are allowed to **vote** for a specified number ("N") of **candidates**.

vote variation

Voting style or feature, including but not limited to the following: **approval voting**, Borda count, **cumulative voting**, **n-of-m voting**, **plurality voting**, **proportional voting**, **range voting**, **ranked choice voting** and super **majority voting**.

vote-by-mail

Method of voting by which **eligible voters** are **mailed ballots** and information packets by the local **election jurisdiction**. **Voters** may be able to return their **marked ballots** by mail, bring them to an election office, or drop them off in secure drop boxes.

Synonyms: VBM, all-mail voting, mail voting, postal voting

vote-capture device

An electronic **voting device** that is used directly by a **voter** to make selections on a **ballot**.

voter

Person permitted to **cast** a **ballot**.

voter intent

A cognitive construct, formed by the **voter**, that they attempt to express through actions taken to mark, verify, and **cast** the issued **ballot**.

voter intent standard

A **standard** for counting ballots that aims to ensure that **ballots** are counted in accordance with the goals of the **voter**, using written rules for both human processes and machine algorithms to ensure that all ballots marked in a similar way are counted in the same way.

voter verifiable

A **voting system** feature that provides the **voter** an opportunity to verify that their **contest selections** are being **recorded** correctly before the **ballot** is **cast**.

voter verified paper audit trail

A paper document that the **voter** can review before officially **casting** their **ballot**.

Synonyms: VVPAT

voter-facing scanner

An electronic **voting device** that:

- accepts hand-marked or BMD-produced **paper ballots** one sheet at a time;
- is usually used for **in-person voting**;
- permits **election workers** to open and close the **polls**;
- scans a **ballot** and rejects it if either unreadable or un-processable;
- detects, interprets and validates **contest selections**;
- notifies the **voter** of voting exceptions (such as **undervotes** or **overvotes**) or unreadable marks;
- stores accepted ballots in a secure container;
- sorts or otherwise marks ballots or **ballot images** that need subsequent human review; and
- **tabulates** and **reports contest** results after polls are closed.

This unit was previously referred to as **precinct count** optical scanner or PCOS.

Synonyms: PCOS, precinct-count optical scanner

voting device

Device that is part of the **voting system**.

voting process

Entire array of procedures, people, resources, equipment, and locations associated with conducting **elections**.

voting session

A collection of activities including **ballot** issuance, **voter** interaction with the **vote-capture device**, voting, verification, and casting.

voting station

The location within a **polling place** where **voters** may **record** their **votes**. A voting station includes the area, location, booth, or enclosure where voting takes place.

voting system

Equipment (including **hardware**, **firmware**, and software), materials, and documentation used to:

- define elections and **ballot styles**,
- configure voting equipment,
- identify and validate voting equipment configurations,
- perform logic and accuracy **tests**,
- activate **ballots**,
- capture **votes**,
- **count** votes,
- handle needing special treatment,
- generate **reports**,
- export election data,
- archive election data, and
- produce **records** in support of audits.

voting system software

The executable code and associated configuration files needed for the proper operation of the **voting system**.

voting system test lab

Privately owned testing laboratories that **test voting systems** (and other **election systems**) for **conformance** to the Voluntary Voting System Guidelines (VVSG) or to other requirements, including individual state requirements. VSTLs are periodically reviewed for conformance to National Voluntary Laboratory Accreditation Program (NVLAP) administered by the National Institute for Standards and Technology (NIST).

Synonyms: VSTL

W:

white box testing

Testing based on an analysis of the internal structure of the **component** or system.

Wi-Fi

A **wireless** networking technology that uses radio waves to provide high-speed Internet network connections.

Wide area network

A network that connects computers across metropolitan, regional, and national boundaries. The internet is an example of a WAN.

Synonyms: WAN

wireless

Network connectivity using radio waves instead of wire connections.

write-in option

A type of **contest option** that allows a **voter** to specify a **candidate**, usually not already listed as a contest option. Depending on **election jurisdiction** rules, in some cases only previously approved names will be considered as valid write-in **contest selections**.

Z:

zero report

A **tabulation report** produced at the opening of **polls** to check that there are no stored **votes**.

Appendix B
Requirements Listing

Appendix B: Requirements Listing

The VVSG 2.0 - Principles and Guidelines

Principle 1: High Quality Design

Principle 2: High Quality Implementation

Principle 3: Transparent

Principle 4: Interoperable

Principle 5: Equivalent and Consistent Voter Access

Principle 6: Voter Privacy

Principle 7: Marked, Verified, and Cast as Intended

Principle 8: Robust, Safe, Usable, and Accessible

Principle 9: Auditable

Principle 10: Ballot Secrecy

Principle 11: Access Control

Principle 12: Physical Security

Principle 13: Data Protection

Principle 14: System Integrity

Principle 15: Detection and Monitoring

Principle 1: High Quality Design

The voting system is designed to accurately, completely, and robustly carry out election processes.

1.1 – The voting system is designed using commonly-accepted election process specifications.

1.1.1 – Election definition
- 1.1.1-A – Election definition
- 1.1.1-B – Election definition details
- 1.1.1-C – Define political geographies
- 1.1.1-D – Serve multiple or split precincts and election districts
- 1.1.1-E – Identifiers
- 1.1.1-F – Definition of parties and contests
- 1.1.1-G – Voting methods
- 1.1.1-H – Election definition accuracy
- 1.1.1-I – Voting options accuracy
- 1.1.1-J – Confirm recording of election definition
- 1.1.1-K – Election definition distribution
- 1.1.1-L – Define ballot styles
- 1.1.1-M – Auto-format
- 1.1.1-N – Include contests
- 1.1.1-O – Exclude contests
- 1.1.1-P – Nonpartisan formatting
- 1.1.1-Q – Jurisdiction-dependent content
- 1.1.1-R – Primary elections, associate contests with parties
- 1.1.1-S – Ballot rotation
- 1.1.1-T – Ballot configuration in combined or split precincts
- 1.1.1-U – No advertising
- 1.1.1-V – Ballot style distribution
- 1.1.1-W – Ballot style identification
- 1.1.1-X – Retaining, modifying, reusing definitions
- 1.1.1-Y – Ballot style protection
- 1.1.1-Z – Data inputs and outputs

1.1.2 – Equipment setup
- 1.1.2-A – Equipment setup
- 1.1.2-B – Built-in self-test and diagnostics
- 1.1.2-C – Verify proper preparation of ballot styles
- 1.1.2-D – Verify proper installation of ballot styles
- 1.1.2-E – Verify compatibility between software and ballot styles
- 1.1.2-F – Test ballots
- 1.1.2-G – Test all ballot positions
- 1.1.2-H – Test Cast Vote Records
- 1.1.2-I – Test codes and images
- 1.1.2-J – Testing calibration
- 1.1.2-K – Ballot marker readiness
- 1.1.2-L – L&A testing, no side-effects
- 1.1.2-M – Status and readiness reports
- 1.1.2-N – Pre-election reports
- 1.1.2-O – Readiness reports for each polling place
- 1.1.2-P – Readiness reports, precinct tabulation
- 1.1.2-Q – Readiness reports, central tabulation
- 1.1.2-R – Readiness reports, public network test ballots

1.1.3 – Opening the Polls
- 1.1.3-A – Opening the polls
- 1.1.3-B – Verify L&A performed
- 1.1.3-C – Prevent opening the polls
- 1.1.3-D – Non-zero totals
- 1.1.3-E – Scanners and ballot marking devices - verify activation
- 1.1.3-F – Scanners and ballot marking devices - enter voting mode

1.1.4 - Ballot Activation
- 1.1.4-A – Ballot activation
- 1.1.4-A.1 – One cast ballot per session
- 1.1.4-A.2 – Contemporaneous record
- 1.1.4-A.3 – Control ballot configuration

1.1.5 - Casting
- 1.1.5-A – Voting methods when casting
- 1.1.5-B – N-of-M voting
- 1.1.5-C – Yes/no measures and multiple-choice measures
- 1.1.5-D – Indicate party affiliations and endorsements
- 1.1.5-E – Closed primaries
- 1.1.5-F – Open primaries
- 1.1.5-G – Write-ins
- 1.1.5-H – Write-in reconciliation
- 1.1.5-I – Ballot rotation for contest options
- 1.1.5-J – Straight party voting
- 1.1.5-K – Cross-party endorsement
- 1.1.5-L – Precinct splits
- 1.1.5-M – Cumulative voting
- 1.1.5-N – Ranked choice voting
- 1.1.5-O – Recallable ballots

1.1.5-P – Review-required ballots

1.1.6 – Recording Voter Choices

1.1.6-A – Casting and recording

1.1.6-B – Secure ballot boxes

1.1.6-C – Prevent counter overflow

1.1.6-D – Ballot orientation

1.1.6-E – Records consistent with feedback to voter

1.1.6-F – Record contest selection information

1.1.6-G – Record write-in information

1.1.6-H – Record election and contest information

1.1.6-I – Record ballot selection override information

1.1.6-J – Record detected mark information

1.1.6-K – Record audit information

1.1.7 – Ballot handling for paper ballot scanners

1.1.7-A – Ballot handling functions for scanners

1.1.7-B – Detect and prevent ballot style mismatches

1.1.7-C – Detect and reject ballots that are oriented incorrectly

1.1.7-D – Ballot separation when batch feeding

1.1.7-E – Overvotes, undervotes, blank ballots

1.1.7-F – Write-ins

1.1.7-G – Ability to clear misfeed

1.1.7-H – Scan to manufacturer specifications

1.1.7-I – Ignore unmarked contest option positions

1.1.7-J – Accurately detect perfect marks

1.1.7-K – Accurately detect imperfect marks

1.1.7-L – Ignore extraneous marks outside contest option position

1.1.7-M – Ignore extraneous marks inside voting targets

1.1.7-N – Ignore hesitation marks

1.1.7-O – Marginal marks, no bias

1.1.7-P – Repeatability

1.1.8 – Closing the Polls

1.1.8-A – Closing the polls

1.1.8-B – No voting when polls are closed

1.1.8-C – Poll closing integrity check

1.1.8-D – Report on poll closing process

1.1.8-E – Prevent reopening polls

1.1.9 – Tabulation

1.1.9-A – Voting methods when tabulating

1.1.9-B – N-of-M voting

1.1.9-C – Yes/no measure and multiple-choice measure

1.1.9-D – Recallable ballots

1.1.9-E – Accept or reject recallable ballots individually

1.1.9-F – Accept or reject recallable ballots by category

1.1.9-G – Primary elections

1.1.9-H – Write-ins

1.1.9-I – Support write-in reconciliation

1.1.9-K – Ballot rotation

1.1.9-L – Straight party voting

1.1.9-M – Tabulating straight party votes

1.1.9-N – Cross-party endorsement

1.1.9-O – Precinct splits

1.1.9-P – Cumulative voting

1.1.9-Q – Ranked choice voting

1.1.10 – Reporting Results

1.1.10-A – Post-election reports

1.1.10-B – Reporting device consolidation

1.1.10-C – Reporting is non-destructive

1.1.10-D – Ballot and vote counts

1.1.10-E – Report all votes cast

1.1.10-F – Account for all cast ballots and all valid votes

1.1.10-G Discrepancies detectable

1.1.10-H – Reporting combined precincts

1.1.10-I – Precinct reporting devices, no tallies before polls close

1.1.10-J – Report categories of cast ballots

1.1.10-K – Report read ballots by party

1.1.10-L – Report counted ballots by contest

1.1.10-M – Report votes for each contest option

1.1.10-N – Report overvotes for each contest

1.1.10-O – Reporting overvotes, ad hoc queries

1.1.10-P – Report undervotes for each contest

1.1.10-Q – Ranked choice voting, report results

1.1.10-R – Include all categories of votes

1.1.10-S – Post-election reports in common data format

1.1.10-T – CVR export and import in common data format

1.1.10-U – Reports are time stamped

1.2 – The voting system is designed to function correctly under real-world operating conditions.

1.2-A – Assessment of accuracy

1.2-A.1 – Minimum ballot positions

1.2-A.2 – Ballot position distribution

1.2-A.3 – Mark quality

1.2-B – Assessment of reliability

1.2-B.1 – Continuous operation – typical environmental conditions

1.2-B.2 – Continuous operation – varied environmental conditions

1.2-B.3 – Failure Modes and Effect Analysis (FEMA)

1.2-C – No single point of failure

1.2-D – Protect against failure of input and storage devices

1.2-E – Reliably detectable marks

1.2-F – Misfeed rate benchmark

1.2-G – Respond gracefully to stress of system limits

1.2-H – Handle realistic volume

1.3 – Voting system design supports evaluation methods enabling testers to clearly distinguish systems that correctly implement specified properties from those that do not.

1.3-A – Identifiability of basic and compound system components

1.3-B – Comprehensible processes that form system configurations

1.3-C – Observable configurations via plausible observation methods

1.3-D – Identifiable resolution limits for observation methods

1.3-E – Description of observational noise and consequences for observational methods

1.3-F – Explicitly-stated performance criteria

1.3-G – Creation and execution of evaluation methods

Principle 2: High Quality Implementation

The voting system is implemented using high quality best practices.

2.1 - The voting system and its software are implemented using trustworthy materials and best practices in software development.

2.1-A – Acceptable programming languages

2.1-B – COTS language extensions are acceptable

2.1-C – Acceptable coding conventions

2.1-D – Records last at least 22 months

2.1.1 – Workmanship

2.1.1-A – General build quality

2.1.1-B – High quality products

2.1.1-C – High quality parts

2.1.1-D – Suitability of COTS components

2.1.1-E – Durability

2.1.1-F – Durability of paper

2.1.2 – Maintainability

2.1.2-A – Electronic device maintainability

2.1.2-B – System maintainability

2.1.2-C – Nameplate and labels

2.2 – The voting system is implemented using best practice user-centered design methods that consider a wide range of representative voters, including those with and without disabilities, and election workers.

2.2-A – User-centered design process

2.3 - Voting system logic is clear, meaningful, and well-structured.

2.3-A – Block-structured exception handling

2.3-B – Legacy library units

2.3-C – Separation of code and data

2.3-D – Hard-coded passwords and keys

2.3.1 – Software flow

2.3.1-A – Unstructured control flow

2.3.1-B – Goto

2.3.1-C – Intentional exceptions

2.3.1-D – Unstructured exception handling

2.4 - Voting system structure is modular, scalable, and robust.

2.4-A – Modularity

2.4-B – Module testability

2.4-C – Module size and identification

2.4-D – Lookup tables in separate files

2.5 - The voting system supports system processes and data with integrity.

2.5-A – Self-modifying code

2.5-B – Unsafe concurrency

2.5.1 – Code integrity

2.5.1-A – COTS compilers

2.5.1-B – Interpreted code, specific COTS interpreter

2.5.1-C – Prevent tampering with code

2.5.1-D – Prevent tampering with data

2.5.2 – Input/output errors

2.5.2-A – Monitoring and defending for I/O errors

2.5.2-B – Validate and filter input

2.5.2-C – Detect garbage input

2.5.2-D – Defend against garbage input

2.5.3 – Output protection

2.5.3-A – Escaping and encoding output

2.5.3-B – Sanitize output

2.5.3-C – Stored injection

2.5.4 – Error handling

2.5.4-A – Mandatory internal error checking

2.5.4-B – Array overflows

2.5.4-C – Buffer overflows

2.5.4-D – CPU traps

2.5.4-E – Garbage input parameters

2.5.4-F – Numeric overflows

2.5.4-G – Uncontrolled format strings

2.5.4-H – Recommended internal error checking

2.5.4-I – Pointers

2.5.4-J – Memory mismanagement

2.5.4-K – Nullify freed pointers

2.5.4-L – React to errors detected

2.5.4-M – Election integrity monitoring

2.5.4-N – SQL injection

2.5.4-O – Parameterized queries

2.6 - The voting system handles errors robustly and gracefully recovers from failure.

2.6-A – Surviving device failure

2.6-B – No compromising voting or audit data

2.6-C – Surviving component failure

2.6-D – Controlled recovery

2.6-E – Nested error conditions

2.6-F – Reset CPU error states

2.6-G – Coherent checkpoints

2.7 - The voting system performs reliably in anticipated physical environments.

2.7-A – Ability to support maintenance and repair physical environment conditions – non-operating

2.7-B – Ability to support transport and storage physical environment conditions – non-operating

2.7-C – Ability to support storage temperatures in physical environment – non-operating

2.7-D – Ability to support storage humidity levels in physical environment – non-operating

2.7-E – Ability to operate as intended at low and high temperatures - operating

2.7-F – Ability to operate as intended at specified humidity conditions - operating

2.7.1 – Ability to withstand electrical disturbances

2.7.1-A – Electrical disturbances

2.7.1-B – FCC Part 15 Class A and B conformance

2.7.1-C – Power supply from energy service provider

2.7.1-D – Power port connection to the facility power supply

2.7.1-E – Leakage from grounding port

2.7.1-F – Outages, sags, and swells

2.7.1-G – Withstand conducted electrical disturbances

2.7.1-H – Emissions from other connected equipment

2.7.1-I – Electrostatic discharge immunity

2.7.1-J – Radiated radio frequency emissions

Principle 3: Transparent

The voting system and voting processes are designed to provide transparency.

3.1 – The documentation describing the voting system design, operation, accessibility features, security measures, and other aspects of the voting system can be read and understood.

3.1.1 – System overview

3.1.1-A – System overview documentation

3.1.1-B – System overview, functional diagram

3.1.1-C – System description

3.1.1-D – Identify software and firmware by origin

3.1.1-E – Traceability of procured software

3.1.2 – System performance

3.1.2-A – System performance

3.1.2-B – Maximum tabulation rate

3.1.2-C – Reliably detectable marks

3.1.2-D – Processing capabilities

3.1.3 – System security documentation

3.1.3-A – System security

3.1.3-B – Access control implementation

3.1.3-C – Physical security

3.1.3-D – Audit Procedures

3.1.3-E – Risk Analysis

3.1.4 – Software Installation

3.1.4-A – Software installation

3.1.4-B – Software information

3.1.4-C – Software location information

3.1.4-D – Election specific software identification

3.1.4-E – Installation software and hardware

3.1.4-F – Software installation procedure

3.1.4-G – Compiler installation prohibited

3.1.4-H – Baseline binary image creation

3.1.4-I – Programmed device configuration replication

3.1.4-J – Software installation record creation

3.1.4-K – Procurement of voting system software

3.1.4-L – Open market procurement of COTS software

3.1.4-M – Erasable storage media preparation

3.1.4-N – Unalterable storage media

3.1.5 – System operations

3.1.5-A – Operations manual

3.1.5-B – Support training

3.1.5-C – Functions and modes

3.1.5-D – Roles

3.1.5-E – Conditional actions

3.1.5-F – References

3.1.5-G – Operational environment

3.1.5-H – Readiness testing

3.1.5-I – Features

3.1.5-J – Operating procedures

3.1.5-K – Support

3.1.5-L – Transportation

3.1.6 – System Maintenance

3.1.6-A – System maintenance manual

3.1.6-B – General contents

3.1.6-C – Maintenance viewpoint

3.1.6-D – Equipment overview details

3.1.6-E – Maintenance procedures

3.1.6-F – Preventive maintenance procedures

3.1.6-G – Troubleshooting procedures

3.1.6-H – Troubleshooting procedure details

3.1.6-I – Special equipment

3.1.6-J – Parts and materials

3.1.6-K – Approved parts list

3.1.6-L – Marking devices

3.1.6-M – Approved manufacturers

3.1.6-N – Ballot stock specification

3.1.6-O – Ballot stock specification criteria

3.1.6-P – Printer paper specification

3.1.6-Q – System maintenance, maintenance environment

3.1.6-R – System maintenance, maintenance support and spares

3.1.7 – Training material

3.1.7-A – Training requirements

3.1.7-B – Personnel

3.1.7-C – User functions versus manufacturer functions

3.1.7-D – Training requirements

3.2 – The processes and transactions, both physical and digital, associated with the voting system are readily available for inspection.

3.2-A – Setup inspection process

3.2-B – Minimum properties included in the setup inspection process

3.2-C – Setup inspection record generation

3.2-D – Installed software identification procedure

3.2-E – Software integrity verification procedure

3.2-F – Election information value

3.2-G – Maximum and minimum values of election information storage locations

3.2-H – Variable value inspection procedure

3.2-I – Backup power operational range

3.2-J – Backup power inspection procedure

3.2-K – Cabling connectivity inspection procedure

3.2-L – Communications operational status inspection procedure

3.2-M – Communications on/off status inspection procedure

3.2-N – Quantity of voting equipment

3.2-O – Consumable inspection procedure

3.2-P – Calibration of voting device components

3.2-Q – Checklist of properties to be inspected

3.3 – The public can understand and verify the operations of the voting system throughout the entirety of the election.

3.3-A – System security, system event logging

3.3-B – Specification of common data format usage

3.3-C Bar and other codes

3.3-D Encodings

3.3-E Audit

Principle 4: Interoperable

The voting system is designed to support interoperability in its interfaces to external systems, its interfaces to internal components, its data, and its peripherals.

4.1 – Voting system data that is imported, exported, or otherwise reported, is in an interoperable format.

4.1-A – Data export and exchange format

4.1-B – Election programming data input and output

4.1-C – Tabulator report data

4.1-D – Exchange of cast vote records (CVRs)

4.1-E – Exchange of voting device election event logs

4.1-F – Voting device event code documentation

4.1-G – Specification of common format usage

4.2 - Standard, publicly-available formats for other types of data not addressed by NIST CDF specifications are used.

4.2-A – Standard formats

4.2-B – Public documented manufacturer formats

4.3 - Widely-used hardware interfaces and communications protocols are used.

4.3-A – Standard device interfaces

4.4 - Commercial-off-the-shelf (COTS) devices can be used if they meet all applicable VVSG requirements.

4.4-A – COTS devices meet applicable requirements

Principle 5: Equivalent and Consistent

All voters can access and use the voting system regardless of their abilities, without discrimination.

5.1 – Voters have a consistent experience throughout the voting process within any method of voting.

5.1-A – Voting methods and interaction modes

5.1-B – Languages

5.1-C – Vote records

5.1-D – Accessibility features

5.1-E – Reading paper ballots

5.1-F – Accessibility documentation

5.2 – Voters receive equivalent information and options in all modes of voting.

5.2.A – No bias

5.2-B – Presenting content in all languages

5.2-C – Information in all modes

5.2-D – Audio synchronized

5.2-E – Sound cues

5.2-F – Preserving votes

Principle 6: Voter Privacy

Voters can mark, verify, and cast their ballot privately and independently.

6.1 - The voting process preserves the privacy of the voter's interaction with the ballot, modes of voting, and vote selections.

6.1-A – Preserving privacy for voters

6.1-B – Warnings

6.1-C – Enabling or disabling output

6.1.D – Audio privacy

6.2 - Voters can mark, verify, and cast their ballot or other associated cast vote record without assistance from others.

6.2-A - Voter Independence

Principle 7: Marked, Verified, and Cast as Intended

Ballots and vote selections are presented in a perceivable, operable, and understandable way and can be marked, verified, and cast by all voters.

7.1 – The default voting system settings present a ballot usable for the widest range of voters, and voters can adjust settings and preferences to meet their needs.

7.1-A – Reset to default settings
7.1-B – Reset by voter
7.1-C – Default contrast
7.1-D – Contrast options
7.1-E – Color conventions
7.1-F – Using color
7.1-G – Text size (electronic display)
7.1-H – Scaling and zooming (electronic display)
7.1-I – Text size (paper)
7.1-J – Sans-serif font
7.1-K – Audio settings
7.1-L – Speech frequencies
7.1-M – Audio comprehension
7.1-N – Tactile keys
7.1-O – Toggle keys
7.1-P – Identifying controls

7.2 – Voters and election workers can use all controls accurately, and voters have direct control of all ballot changes.

7.2-A – Display and interaction options
7.2-B – Navigation between contests
7.2-C – Voter control
7.2-D – Scrolling
7.2-E – Touchscreen gestures
7.2-F – Voter speech
7.2.G – Voter control of audio
7.2-H – Accidental activation
7.2.-I – Touch area size
7.2-J – Paper ballot target areas
7.2-K – Key operability
7.2-L – Bodily contact
7.2-M – No repetitive activation
7.2-N – System response time
7.2-O – Inactivity alerts
7.2-P – Floor space
7.2-Q – Physical dimensions
7.2-R – Control labels visible

7.3 – Voters can understand all information as it is presented, including instructions, messages from the system, and error messages.

7.3-A – System-related errors
7.3-B – No split contests
7.3-C – Contest information
7.3-D – Consistent relationship
7.3-E – Feedback
7.3-F – Correcting the ballot
7.3-G – Full ballot selections review
7.3-H – Overvotes
7.3-I – Undervotes
7.3-J – Notification of casting
7.3-K – Warnings, alerts, and instructions
7.3-L – Icon labels
7.3-M – Identifying languages
7.3-N – Instructions for voters
7.3-O – Instructions for election workers
7.3-P – Plain language

Principle 8: Robust, Safe, Usable, and Accessible

The voting system and voting processes provide a robust, safe, usable, and accessible experience.

8.1 – The voting system's hardware, software, and accessories are robust and do not expose users to harmful conditions.

8.1-A – Electronic display screens

8.1-B – Flashing

8.1-C – Personal Assistive Technology (PAT)

8.1-D – Secondary ID and biometrics

8.1-E – Standard audio connectors

8.1-F – Discernable audio jacks

8.1-G – Telephone style handset

8.1-H – Sanitized headphones

8.1-I – Standard PAT jacks

8.1-J – Hearing aids

8.1-K – Eliminating hazards

8.2 – The voting system meets currently accepted federal standards for accessibility.

8.2-A – Federal standards for accessibility

8.3 – The voting system is evaluated for usability with a wide range of representative voters, including those with and without disabilities.

8.3-A – Usability tests with voters

8.4 – The voting system is evaluated for usability with election workers.

8.4-A – Usability tests with election workers

Principle 9: Auditable

The voting system is auditable and enables evidence-based elections.

9.1 - An error or fault in the voting system software or hardware cannot cause an undetectable change in election results.

9.1.1 – Software independence

9.1.1-A – Software independent

9.1.1-B – Paper-based or cryptographic E2E system

9.1.1-C –Mechanism documentation

9.1.2 – Tamper evidence

9.1.2-A – Tamper evident records

9.1.2-B – Tamper-evident record creation

9.1.3 – Voter verification

9.1.3-A – Records for voter verification

9.1.3-B – Identification of errors

9.1.3-C – Ballot error correction

9.1.3-D – Voter reported errors

9.1.4 – Auditable

9.1.4-A – Auditor verification

9.1.4-B – Auditable with compromised software, firmware, or hardware

9.1.4-C – Documented procedure

9.1.5 – Paper records

9.1.5-A – Paper record production

9.1.5-B – Paper record retention

9.1.5-C – Paper record intelligibility

9.1.5-D – Matching selections

9.1.5-E – Paper record transparency and interoperability

9.1.5-F – Unique identifier

9.1.5-G – Preserving software independence

9.1.6 – E2E Cryptography

9.1.6-A – Cryptographic E2E transparency

- 9.1.6-A.1 – Verified Cryptographic Protocol
- 9.1.6-A.2 – Public availability of E2E cryptographic protocol implementation
- 9.1.6-B – Cryptographic ballot selection verification by voter• 9.1.6-B.1 – Methods for cryptographic ballot selection verification

9.1.6-C – Ballot receipt

9.1.6-D – Evidence export

9.1.6-E– Mandatory ballot availability

9.1.6-F – Verification of encoded votes documentation

9.1.6-G – Verifier reference implementation

- 9.1.6-H – Privacy preserving, universally verifiable ballot tabulation

9.1.7 – Audit support

9.1.7-A – Number of ballots to check

9.1.7-B – No fixed margin of error

9.1.7-C – Random number usage

9.2 - The voting system produces readily available records that provide the ability to check whether the election outcome is correct and, to the extent possible, identify the root cause of any irregularities.

9.2-A – Compliance audit procedures

9.2-B – General post-election audit procedures

9.2-C – Generating CVRs

9.2-D – Reporting intermediate results

9.2-E – Reporting unusual audit events

9.2-F – Reporting format

9.2-G – Ballot count

9.3 - Voting system records are resilient in the presence of intentional forms of tampering and accidental errors.

9.3-A – Data protection requirements for audit records

9.4 - The voting system supports efficient audits.

9.4-A – Efficient compliance audit

9.4-B – Efficient risk-limiting audit

9.4-C – Unique ballot identifiers

9.4-D – Multipage ballots

Principle 10: Ballot Secrecy

The voting system protects the secrecy of voters' ballot selections.

10.1 - Ballot secrecy is maintained throughout the voting process.

10.1-A – System use of voter information

10.2 - The voting system does not contain nor produce records, notifications, information about the voter, or other election artifacts that can be used to associate the voter's identity with the voter's intent, choices, or selections.

10.2.1 – Voter associations

10.2.1-A – Direct voter associations

10.2.1-B – Indirect voter associations

10.2.1-C – Use of indirect voter associations

10.2.1-D – Election worker selection of indirect associations

10.2.1-E – Isolated storage location

10.2.1-F – Confidentiality for indirect association

10.2.2 – Identification in vote records

10.2.2-A – Identifiers used for audits

10.2.2-B – No voter record order information

10.2.2-C – Identifying information in voter record file names

10.2.2-D – Non-memorable identifiers and associations

10.2.2-E – Aggregating and ordering

- 10.2.2-F – Random number generation

10.2.3 – Access to cast vote records (CVR)

10.2.3-A – Least privilege access to store

10.2.3-B – Limited access

10.2.3-C – Authorized access

10.2.3-D – Digital voter record access log

10.2.4 – Voter information in other devices and artifacts

10.2.4-A – Voting information in receipts

10.2.4-B – Ballot secrecy for receipts

10.2.4-C – Logging of ballot selections

10.2.4-D – Activation device records

Principle 11: Access Control

The voting system authenticates administrators, users, devices, and services before granting access to sensitive functions.

11.1 - The voting system enables logging, monitoring, reviewing, and modifying of access privileges, accounts, activities, and authorizations.

11.1-A – Logging activities and resource access

11.1-B – Voter information in log files

11.1-C – Preserving log integrity

11.1-D – On-demand access to logs

11.2 - The voting system limits the access of users, roles, and processes to the specific functions and data to which each entity holds authorized access.

11.2.1 – Authorized access

11.2.1-A – Ensuring authorized access

11.2.1-B – Modifying authorized user lists

11.2.1-C – Access control by voting stage

11.2.1-D – Access control configuration

11.2.1-E – Administrator modified permissions

11.2.1-F – Authorized assigning groups or roles

11.2.2 – Role-based access control

11.2.2-A – Role-based access control standard

11.2.2-B – Minimum groups or roles

11.2.2-C – Minimum group or role permissions

11.2.2-D – Applying permissions

11.3 - The voting system supports strong, configurable authentication mechanisms to verify the identities of authorized users and includes multi-factor authentication mechanisms for critical operations.

11.3.1 – Access control mechanism

11.3.1-A – Access control mechanism application

11.3.1-B – Multi-factor authentication for critical operations

11.3.1-C – Multi-factor authentication for administrators

11.3.2 – Username and password

11.3.2-A – Username and password management

11.3.2-B – Password complexity

- 11.3.2-B.1 – Specify password complexity

11.3.2-C – Password blacklist

11.3.2-D – Usernames within passwords

11.4 - The voting system's default access control policies enforce the principles of least privilege and separation of duties.

11.4-A – Least privilege for access policies

11.4-B – Separation of duties

11.5 - Logical access to voting system assets are revoked when no longer required.

11.5-A – Access time period

11.5-B – Account lockout

11.5-C – Lockout time duration

Principle 12: Physical Security

The voting system prevents or detects attempts to tamper with voting system hardware.

12.1 - The voting system supports mechanisms to detect unauthorized physical access.

12.1-A – Unauthorized physical access

12.1-B – Unauthorized physical access alarm

12.1-C – Disconnecting a physical device

12.1-D – Logging of physical connections and disconnections

12.1-E – Logging door cover and panel status

12.1-F – Secure containers

12.1-G – Secure physical locks

12.1-H – Secure locking system key

12.1-I – Backup power for power-reliant countermeasures

12.2 - The voting system only exposes physical ports and access points that are essential to voting operations.

12.2-A – Physical port and access least functionality

12.2-B – Physical port auto-disable

12.2-C - Physical port restriction

12.2-D – Disabling ports

12.2-E – Logging enabled and disabled ports

Principle 13: Data Protection

The voting system protects data from unauthorized access, modification, or deletion.

13.1 - The voting system prevents unauthorized access to or manipulation of configuration data, cast vote records, transmitted data, or audit records.

13.1.1 – Configuration file

13.1.1-A – Authentication to access configuration file

13.1.1-B – Authentication to access configuration file on EMS

13.1.1-C – Authentication to access configuration file for network appliances

13.1.2 – Election records

13.1.2-A – Integrity protection for election records

13.1.2-B – EMS integrity protection for election records

13.2 – The source and integrity of electronic tabulation reports are verifiable.

13.2-A – Signing stored electronic voting records

13.2-B – Signing electronic voting records prior to transmission

13.2-C – Cryptographic verification of electronic voting records

13.3 - All cryptographic algorithms are public, well-vetted, and standardized.

13.3-A – Cryptographic module validation

13.3-B– E2E cryptographic voting protocols

13.3-C – Cryptographic strength

13.3-D – MAC cryptographic strength

13.3-E – Key management documentation

13.4 - The voting system protects the integrity, authenticity, and confidentiality of sensitive data transmitted over all networks

13.4-A – Mutual authentication of endpoints

13.4-B – Confidentiality protection for transmitted data

13.4-C – Integrity protection for transmitted data

13.4-D – Verification of election data

Principle 14: System Integrity

The voting system performs its intended function in an unimpaired manner, free from unauthorized manipulation of the system, whether intentional or accidental.

14.1 - The voting system uses multiple layers of controls to provide resiliency against security failures or vulnerabilities.

14.1-A – Risk assessment documentation

14.1-B – Addressing and accepting risk

14.1-C – System security architecture description

14.1-D – Procedural and operational security

14.2 - The voting system limits its attack surface by avoiding unnecessary code, data paths, connectivity, and physical ports, and by using other technical controls.

14.2-A – Extraneous processes and services

14.2-B – Non-essential features

14.2-C – Network status indicator

14.2-D – Wireless Communication Restrictions

14.2-D.1 – Wireless network status indicator

14.2-E – External Network Restrictions

14.2-F – Secure configuration and hardening

14.2-G – Secure configuration and hardening documentation

14.2-H – Unused code

14.2-I – Exploit mitigation technologies within platform

14.2-J – Application use of exploit mitigation technologies

14.2-K – Importing software libraries

14.2-L – Physical port restriction

14.2-M – Known vulnerabilities

14.2-N – List of known vulnerabilities

14.3 - The voting system maintains and verifies the integrity of software, firmware, and other critical components.

14.3-A – Supply chain risk management strategy

14.3-B – Criticality analysis

14.3-B.1 –Bill of Materials

14.3.1 – Boot integrity

14.3.1-A – Cryptographic boot verification

14.3.1-B – Preventing of boot on error

14.3.1-C – Logging of verification failure

14.3.2 – Software integrity

14.3.2-A – Installing software

14.3.2-B – Software verification for installation

14.3.2-C – Software whitelisting

14.3.2-D – Integrity protection for software whitelists

14.4 - Voting system software updates are authorized by an administrator prior to installation.

14.4-A – Authenticated operating system updates

14.4-B – Authenticated application updates

14.4-C – Authenticated firmware updates

Principle 15: Detection and Monitoring

The voting system provides mechanisms to detect anomalous or malicious behavior.

15.1 - Voting system equipment records important activities through event logging mechanisms, which are stored in a format suitable for automated processing.

15.1-A – Event logging

15.1-B – Exporting logs

15.1-C – Logging voter information

15.1-D – Logging event types

15.1-E – Configuration file access log

15.2 - The voting system generates, stores, and reports all error messages as they occur.

15.2-A – Presentation of errors

15.2-B – Documenting error handling

15.2-C – Logging errors

15.2-D – Creating error reports

15.3 - The voting system is designed to protect against malware.

15.3-A – Software verification

15.3.1 – Malware protection

15.3.1-A – Malware protection mechanisms

15.3.1-B – Updatable malware protection mechanisms

15.3.1-C – Documenting malware protection mechanisms

15.3.1-D – Notification of malware detection

15.3.1-E – Logging malware detection

15.3.1-F – Notification of malware remediation

15.3.1-G – Logging malware remediation

15.4 - A voting system with networking capabilities employs appropriate, well-vetted modern defenses against network-based attacks, commensurate with current best practice.

15.4-A – Network architecture documentation

15.4-B – Secure configuration documentation

15.4-B.1 – Documentation for disabled wireless

15.4-C – Firewall and IDS

15.4-D – Least privilege

15.4-E – Rule and policy updates

Appendix C
References

Appendix C: References

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